RUSAL

AUGHINISH

Aughinish Alumina Ltd.

Askeaton, Co. Limerick

IE Licence Reg. P0035-06

Extractive Waste Management Plan

September 2018

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1. Introduction

The Bauxite Residue Disposal Area (BRDA) at RUSAL Aughinish Ltd. (AAL) is a dedicated storage facility, owned, developed and operated by RUSAL Aughinish Ltd. for the permanent deposition of specific bauxite and process residues generated within the alumina refinery.

It is classified as a "waste facility" for "extractive waste" under the Management of Waste from the Extractive Industries Regulations 2009 (S. I. No. 256 of 2009). The facility was further classified a "Category A facility" within the meaning of the Regulations by the Environmental Protection Agency in November 2011.

Condition 8.3.1 of the current IE Licence for the facility (P0035-06) requires the preparation of an Extractive Waste Management Plan (EWMP) for the BRDA.

1.1 Facility and Licence Details

AAL commenced operation in 1983 as a 800,000 tpa (tonnes per annum) alumina refinery supplying aluminium smelters in the EU. In the intervening years, the refinery has been modernised and expanded and is now operating at a 1.95 million tpa alumina production rate. It now accounts for more than 35% of EU alumina production.

Since March 2008, RUSAL Aughinish Ltd. (AAL) has been wholly owned by United Company RUSAL, which is one of the largest integrated aluminium company worldwide. The AAL plant extracts alumina from bauxite ore using the conventional Bayer process. Approximately 70% of the bauxite processed by AAL is imported from Guinea in West Africa with the remainder coming from Trombetas in Brazil. The finished product, alumina, is exported for further processing through smelting to aluminium metal.

A summary of the facilities Licencing history is tabulated below.

Table 1.1 Licencing History at AAL

Licence	Year of Issue	Reason for Change
IPC Licence P0035-01	1998	EPA Act (1992)
IPC Licence P0035-02	2004	Inclusion of CHP
IPC Licence P0035-03	N/A	Application withdrawn
IPPC Licence P0035-04	2008	BRDA extension and production increase
IPPC Licence P0035-05	2012	Inclusion of a gas fired boiler and Calciner conversion to gas
IE Licence P0035-06	2014	Inclusion of a 2nd gas fired boiler

1.2 Site Location

The AAL facility is situated on Aughinish Island, a small island of 450 hectares on the southern shore of the Shannon Estuary in west County Limerick. It is bounded by the Robertstown River and the Poulaweala Creek on its landward sides. The rural areas immediately to the south-east and south-west are generally low-lying, rising gently to the south. Aughinish Island lies within the lower River Shannon Special Area of Conservation. The area is also an SPA under the Birds Directive and Aughinish manages a Bird Sanctuary within its land portfolio.

1.3 Bauxite Residue Disposal Area (BRDA)

The Bauxite Residue Disposal Area (BRDA) is a dedicated storage facility owned, developed and operated by RUSAL Aughinish Ltd for the permanent disposal of specific bauxite and process residues generated within the alumina refinery.

The BRDA consists of the older Phase 1 BRDA and the new Phase 2 BRDA. The Phase 1 BRDA (area ca. 104 ha.) is confined to Aughinish Island. It was commissioned in 1983 as a 70 hectare storage facility and employed screened glacial till as the base liner, as per design standards at that time. It was extended from 70 to 104 hectares in 1996 and the 34 hectare extension was equipped with a synthetic liner. The Phase 2 extension (area ca. 80 ha) is directly south of the Phase 1 and extends across Poulaweala Creek and onto the mainland (the townlands of Island Mac Teige and Glenbane West). It was commissioned in 2011 and is composite lined throughout. Phase 1 and Phase 2 are both active storage areas.

The BRDA has been designed to ensure the long-term stability of the residues – principally red mud which is referred to as bauxite residue. The bauxite residue is retained by a perimeter stack wall constructed of rockfill, which is raised systematically in 2m lifts or stages. There is also a flood tidal defence berm between the BRDA and the Shannon Estuary foreshore that protects the BRDA from wave and tidal erosion. AAL is responsible for the maintenance of this structure.

The BRDA planning permission is to a maximum perimeter raise (Stage 10) of elevation 24 m AMSL resulting in a maximum central elevation of 32 m AMSL. This will provide storage to the year 2031 at current production rates and bauxite grade.

1.4 Legislative Background

The Waste Management Regulations (Management of Waste from the Extractive Industries Regulations S.I. No. 256 of 2009) transpose EU Directive 2006/21 of 15 March 2006 on the management of waste from extractive industries (also known as the “Mining Waste Directive”) into Irish law. The primary purpose of this Directive was to take a Europe-wide initiative to prevent catastrophic failures of containment systems at extractive waste facilities, which present a significant risk to human health and the environment.

The Regulations overlap with other Irish legislation such as the Waste Management Act, the Planning and Development Act and the Local Government (Water Pollution) Act and have been incorporated into the IE licensing regime.

"Extractive Waste" is defined in the Regulations as "waste from the extractive industries within the meaning and the scope of these Regulations", i.e. "waste resulting from the prospecting, extraction, treatment and storage of mineral resources and the working of quarries". A "Waste Facility" is defined as "any area designated for the accumulation or deposit of extractive waste, whether in a solid or liquid state or in solution or suspension".

1.5 Scope of Extractive Waste Management Plan

The component parts of an Extractive Waste Management Plan (EWMP) are defined in Regulation 5 of the Extractive Waste Regulations 2009.

It should be noted that the main components of this EWMP already exist in documentation previously submitted to the EPA. These include:

- The BRDA Operational, Safety and Maintenance Manual
- Risk Assessment & Breakout Study for the BRDA
- Annual Environmental Reports

To avoid unnecessary duplication these are referenced, summarised or included as Appendices where relevant.

1.6 Objectives of Extractive Waste Management Plan

The objectives of the EWMP are the minimisation, appropriate treatment and safe disposal of extractive waste taking into account the principle of sustainable development. To meet these objectives:

- the highest quality bauxite available with the lowest residue factor is processed
- the highest feasible alumina extraction efficiency is targeted to minimise waste generated
- the most efficient washing system is employed to minimise residual caustic in the bauxite residue
- once disposed the bauxite residue is farmed intensively to maximise compaction and minimise residual caustic via atmospheric carbonation

2. Classification of the Waste Facility

The BRDA facility was classified by the EPA as a "Category A" facility under the Extractive Waste Regulations in November 2011. The basis for this classification is that a failure of the BRDA containment structures could result in damage to the habitats within the Lower Shannon and Barrigone Special Areas of Conservation (SAC) bordering the BRDA. The current IE licence P0035-06 for the plant takes this facility classification into account and includes conditions and requirements relating to the management of the BRDA.

The AAL site has an existing safety management system which is certified to Advanced Level 8 of the International Safety Rating System (I.S.R.S). This contains a Major Accident Prevention Policy and an Internal Emergency Plan which apply to the entire facility at Aughinish, both the alumina refinery and the BRDA. These are attached in Appendix 1A and 1B.

In 2013 Limerick City and County Council (as the Principal Response Agency) in consultation with AAL published an External Emergency Plan for a BRDA Containment Failure. This plan was revised in 2016 following a 2015 onsite review which involved all relevant parties. Refer to Appendix 2 for the Plan.

3. Waste Characterisation

Condition 8.4.2 of the IE Licence requires that "Waste to be deposited in the BRDA shall be characterised in accordance with Commission Decision 2009/360/EC (technical requirements for waste characterisation) and any guidance or decisions issued by, or on behalf of, the committee for the Adaption to Scientific and Technical Progress of Directive 2006/21/EC on the management of waste from extractive industries''. The requirements are also listed in Schedule 2 of the 2009 Extractive Waste Regulations.

AAL has refered to the following NSAI standards:

i. Characterisation of Waste - Sampling of waste from extractive indusries (CEN/TR 16365:2012)
ii. Characterisation of Waste - Overall guidance document for characterisation of waste from the extractive industries

3.1 Geological Background

The bauxites processed at AAL are high quality in terms of the percentage available alumina and are among the highest grade processed globally.

While crushing and grinding are undertaken at the AAL plant, the principal factor determining the particle size distribution of the residue is the degree of dissolution of the alumina phase. Once the bauxite passes through digestion its size distribution reduces dramatically due to the chemical grinding effect of the digestion process.

Bauxite residue is composed primarily of iron oxides, sodalite (sodium aluminium silicate), perovskite (calcium titanate) and hydrogarnet (calcium aluminium silicate) and various forms of alumina. It is finely divided with a D50 of <5 microns. As it has been digested in caustic, it inevitably contains residual caustic. A further characteristic of bauxite residue is that the sodalite fraction is effectively solid phase alkalinity. Once caustic is removed, the pH is buffered by the sodalite due to the release of weakly bound sodium carbonate from the sodalite.

Process sand is chemically similar to bauxite residue but has a higher iron oxide content (65% compared to 40% in bauxite residue) and a lower sodalite content. It is two orders of magnitude larger in size than bauxite residue. Because of its size, it is difficult to keep sand in suspension in the washing circuit and it would tend to settle out and block tanks and pipelines and overload rakes. For these reasons, it is removed at the end of digestion and before the residue washing circuit and handled as a separate waste stream.

3.2 The Waste and its Intended Handling

During digestion, the soluble alumina in the bauxite dissolves in the hot caustic solution while the other oxides present in the ore are insoluble in caustic and report as residue. Typically two tonnes of bauxite produce one tonne of alumina and 0.7 tonnes of bauxite residue. The balance is moisture and water of crystallisation. Of the bauxite residue approximately 90% reports as finely divided bauxite residue while the balance reports as coarse process sand.

After digestion, the hot slurry containing alumina in solution and residue in suspension is cooled to atmospheric boiling temperature. Once cooled this stream is passed through sand separators where the heavy sand particles settle out. Sand size ranges from 100 to 1000 microns. The desanded stream is then flocculated and passed across gravity decanters where the bauxite residue is settled out due to the agglomeration properties of the flocculant. Approximately 93% of the bauxite residue consists of finely divided residue with D50 less than 5 microns. This is then sent through 4 stages of counter-current washing to reduce the caustic strength. Up to 2018, there was 3 stages of counter-current washing. However, in 2018 a deep cone thickener was commissioned which is best available technology in the Alumina Industry for caustic recovery. Following washng, the residue is fed to a bank of 8 vacuum drum filters operating in parallel. The vacuum drum filters aspirate a 2mm thick film onto the filter cloth that is wrapped around the rotating drum filter. A hot condensate wash is applied to the surface and this is sucked through the residue film and removed as filtrate providing an efficient displacement wash. The washed residue is discharged from the filters aas a dry cake of typically 63% solids. The associated soda level in the liquid phase is typically less than 10 gpl Na_2O.

The washed and dewatered filter cake discharges into an agitated tank where condensate is added to reduce the viscosity and make the residue paste pumpable. The reduced viscosity residue paste at typically 58% solids discharges from the agitated tank into a centrifugal pump which transfers it into the special high pressure positive displacement pumps. These pumps transfer the washed residue paste to the BRDA via 2 km long high pressure transfer pipelines operating at typically 70-80 bar pressure. This is then directed within the BRDA piping network to the appropriate discharge point.

The recirculating caustic stream in the alumina plant dissolves extractable alumina from bauxite in digestion and re-precipitates it as alumina hydrate in the precipitation circuit. Any losses of caustic are balanced by make-up with fresh caustic. As the same caustic stream is re-used it accumulates whatever other caustic soluble components are present in the bauxite. In this manner the caustic liquor accumulates sodium carbonate, sodium oxalate and sodium humate which are the principal products produced due to the caustic digestion of organic material present in the bauxite ore. If these products were allowed to accumulate un-checked they would eventually render the process ineffiecent. To avoid this it is necessary to remove these impurities at the rate at which they enter the process. This is achieved by taking a side stream of process caustic and evaporating it followed by cooling so that the above impurities exceed their solubility limit in the side stream and salt-out. This product is filtered on vacuum filters to recover as much caustic and aluminate as possible. In this manner, 40-50 tonnes per day of moist salt cake consisting of the impurities above with some entrained caustic and aluminate are produced for disposal to the BRDA. The salt cake is transported by dumper truck on a daily basis to the BRDA where it is dumped into the dedicated salt cake storage cell.

Apart from sand and salt cake, the principal other wastes trucked to the BRDA and deposited at designated locations are:

- Lime grits from the lime slaking plant
- scale and sludges from vessel, bund and pond cleaning operations
- non contaminated refractory from maintenance activities on the calciners and boilers
- construction and demolition waste

Table 3.1 details the type and approximate composition of waste disposed in the BRDA. Permission to deposit any other compatible waste types in the BRDA is sought on a case by case basis in advance from the EPA. These included cooling tower packing (plastic material) contaminated with process residues.

Table 3.1 Process Residues deposited in the BRDA

Waste Stream	Source	European Waste Catalogue (LOW Code)	Hazardous/ Non-Hazardous (LOW Classification)	Quantity disposed in 2017 (tonnes)
Bauxite residue	By-product of production process	01 03 09	Non-Hazardous	1,371,301
Sand	By-product of production process	01 03 06	Non-Hazardous	103,158
Process Waste	Scale & sludge from vessel cleanouts & cleanout of plant effluent storage ponds	01 03 99	Non-Hazardous	15,996
Lime Grits	Lime slaking rejects	01 03 99	Non-Hazardous	5,620
Salt Cake	By-product of production process	01 03 07	Hazardous	18,304
Refractory Waste	From calciner & boiler flue stack maintenace	16 11 04	Non-Hazardous	140

3.2.1 Waste Classification

Appendix 3 contains the Extractive Waste Classification Report issued in 2013. The report examines the various wastes disposed within the Aughinish BRDA and classifies each waste according to the EPA document 'Waste Classification List of Waste & Determining if Waste is Hazardous or Non-hazardous' and associated legislation. The report also explains the basis for each classification.

The report examines the various wastes disposed within the Aughinish BRDA and classifies each waste according to the requirements of Waste Classification List of Waste (LoW) & the EPA document 'Determining if Waste is Hazardous or Non-hazardous' and associated legislation. The study/report also explains the basis for each classification.

The report identifies that the only hazardous waste disposed in the BRDA is 'salt cake' produced in the on-site evaporator and crystalliser unit. Its classification is LOW code 01 03 07*. This material is disposed in a dedicated lined cell within the BRDA.

In addition, report which was submitted to the Agency in October 2015 is attached in Appendix 4. This report summarises an assessment of farmed bauxite residue which employs the current EU legislation as specified by the EU Waste Framework Directive (2008/98/EC), the Hazardous Waste Directive (2000/532/EC) and the Extractive Waste Directive (2006/21/EC). The rport indicates the non-hazardous classification of farmed bauxite residue.

3.2.2 Summary of Waste Classification

The table below summarises the wastes which AAL deposit in the BRDA, namely 'extractive wastes' and 'recovered materials'.

Table 3.2 Extractive Wastes & Recovered Materials to be deposited in the BRDA

Waste Stream	**Source**	**LOW Code**	**Hazardous/ Non-Hazardous (LOW Classification)**
Bauxite residue	By-product of production process	01 03 09	Non-Hazardous
Sand	By-product of production process	01 03 06	Non-Hazardous
Salt Cake	By-product of production process	01 03 07	Hazardous
Lime Grits	Lime slaking rejects	01 03 99	Non-Hazardous
Process Scales & Sludges	Scale & sludge from vessel cleanouts & cleanout of plant effluent storage ponds	01 03 99	Non-Hazardous
Recovered refractory (non-hazardous)	Calciner & boiler unit maintenance. Used for roadway construction within the BRDA	16 11 04	Non-Hazardous
Recovered building rubble	Construction & demolition. Used for roadway construction within the BRDA	17	Inert

Waste Stream	Source	LOW Code	Hazardous/ Non-Hazardous (LOW Classification)
Recovered miscellaneous materials, e.g. cooling tower packing and waste insulation	Process contaminated materials. Used for roadway construction within the BRDA	Depending on type of plastic fill	Non-hazardous

3.3 Geotechnical Behaviour

In this section, the suitable parameters for assessing the intrinsic physical characteristics of the waste taking into account the type of waste facility are identified. The relevant parameters are:

3.3.1 Bauxite Residue

(1) Minerology

a) Bauxite residue consists of porous agglomerated particles containing some 70% to 80% of amorphous material (oxides, hydrated oxides and oxi-hydroxides such as boehmite, goethite and gibbsite) with fine crystals of quartz, heamatite, rutile, titanium and other opaque minerals. A limited number of very coarse heamatite and ilmenite crystals of 10 to 70 microns were observed whilst the remainder were less than 4 microns. Little or no clay minerals are present and the quartz (silica) content is less than 10%. Other silicates include natrodavyne, zeolites, cancrinite and sodalite.

b) Based on the mineralogy, it can be expected that the bauxite residue would not behave as a clay but retain properties similar to a granular silt. However, unlike conventional soils, the amorphous particles could retain water which could have no or limited effect on the properties of the material.

(2) Granulometry

The majority of the material is clay and silt size. About 90% by weight of the bauxite residue is finer than 60 microns and the D50 is approximately 10 microns. A typical particle size distribution of red mud is shown below:

TEST REPORT

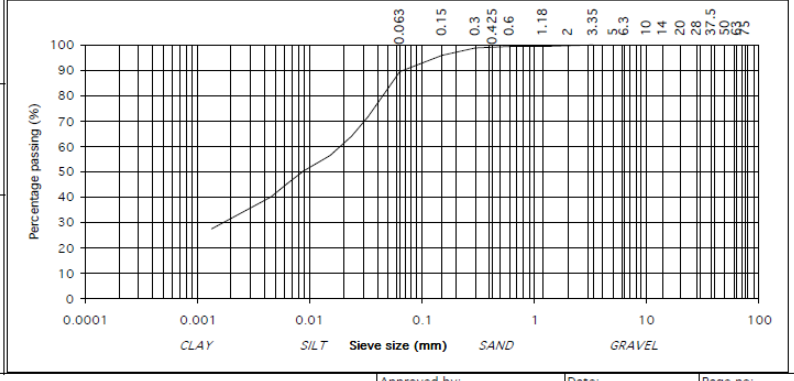
Determination of Particle Size Distribution

Tested in accordance with: BS1377:Part2:1990 , clause 9.2 & 9.5
(note: Sedimentation stage not accredited)

Contract No: 17432 Report No. R57218
Contract: Aughinish
Bh: 1 Carbonated
Sample No. N/A Lab. Sample No. A14/1074
Sample Type: B
Depth (m) N/A Customer: Golder Associates
Date Received 18/03/2014 Date Testing started 09/04/2014
Description: Red slightly sandy, SILT

Remarks

particle size	% passing	
75	100	COBBLES
63	100	
50	100	GRAVEL
37.5	100	
28	100	
20	100	
14	100	
10	100	
6.3	100	
5	100	
3.35	100	
2	100	
1.18	100	SAND
0.6	99	
0.425	99	
0.3	99	
0.15	96	
0.063	90	SILT/CLAY
0.033	72	
0.024	64	
0.015	57	
0.009	50	
0.006	45	
0.005	40	
0.001	28	



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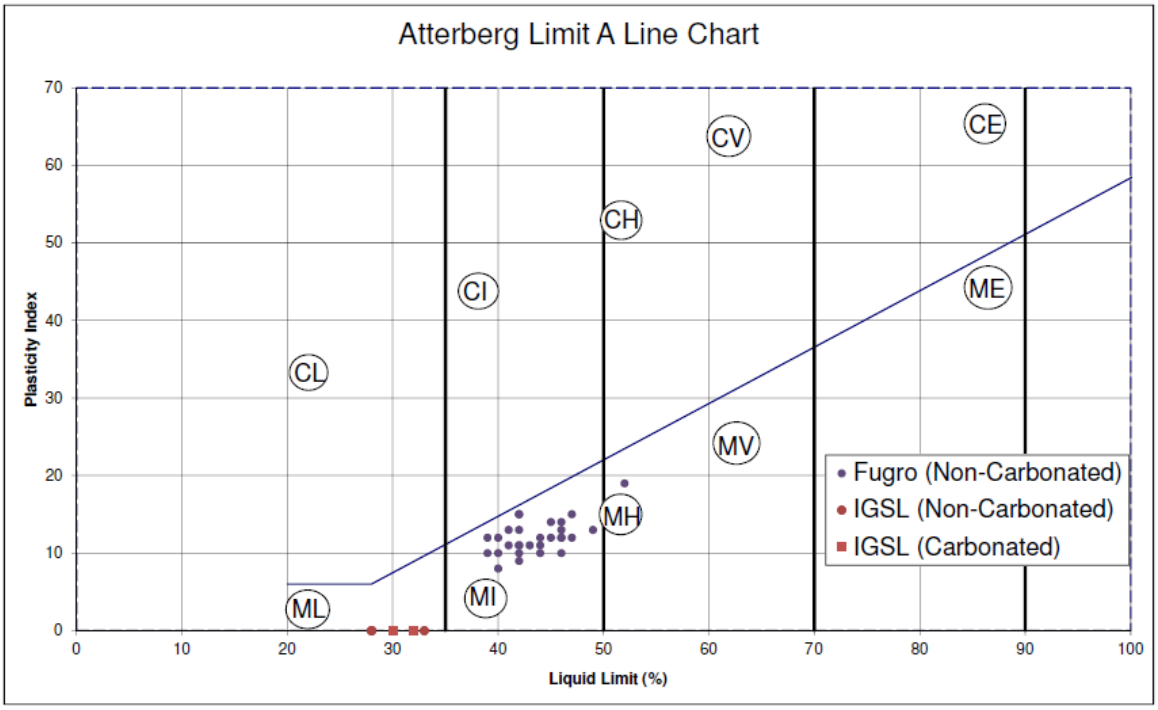
(3) Plasticity

In general the range of liquid limits (LL) are between 39% and 52% with a mean of 44% and the plasticity indices (PI) are between 8% and 19% with a mean of 12% and the results are reasonably consistent. The bauxite residue plots as a silt of intermediate plasticity on the Casagrande chart in the Figure below:

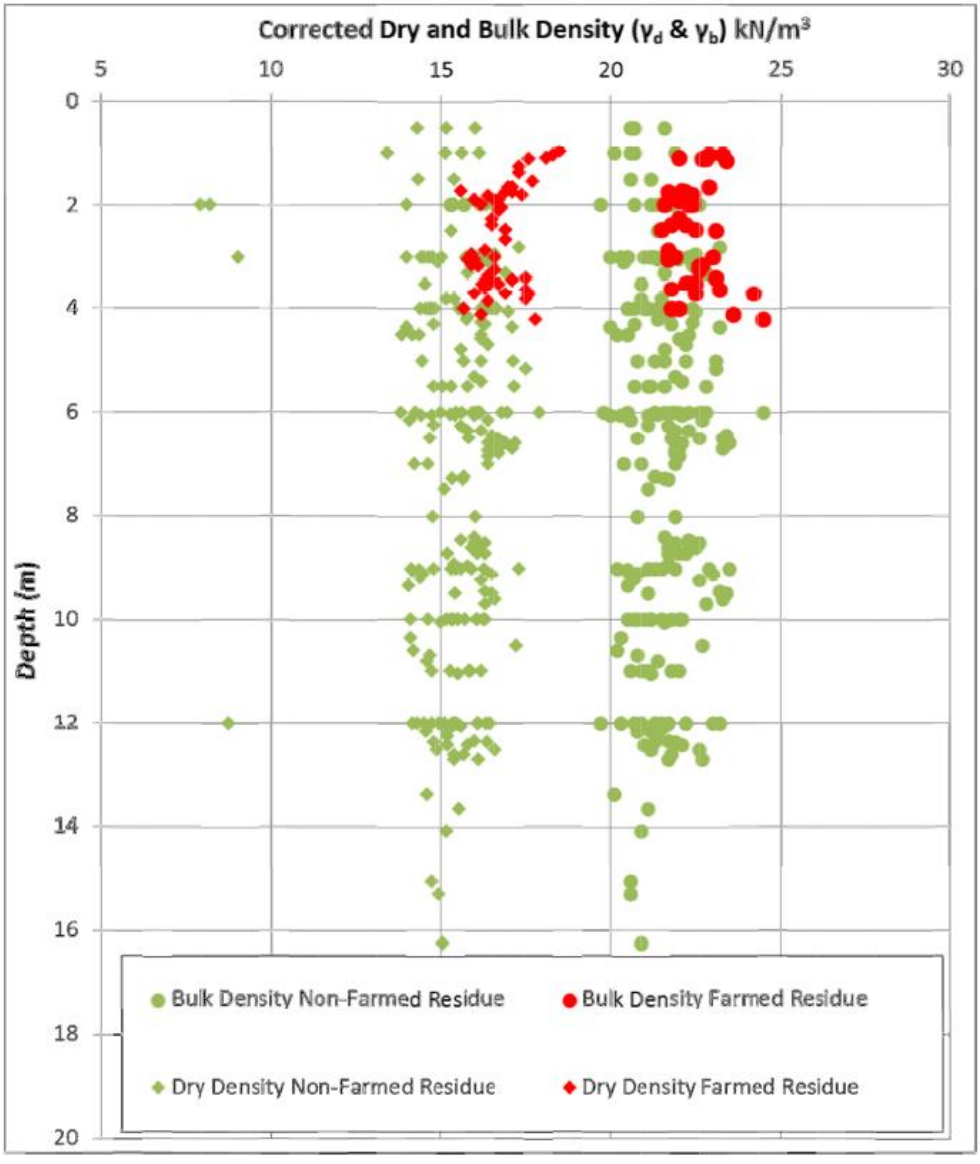


(4) Density

The corrected values for dry and bulk density with depth are shown below. In general the bulk density y_b within the farmed residue ranged from between 21.5 to 24.5 kN/m^3 with a mean value of 22.5 kN/m^3. Within the lower non-farmed residue bulk density y_b ranged from 15.3 to 24.5 kN/m^3 with a mean value of 21.5 kN/m^3.

In general the dry density y_d within the farmed residue ranged from between 15.6 to 18.5 kN/m^3 with a mean value of 16.8 kN/m^3. Within the lower non-farmed residue, dry density y_d ranged from 7.9 to 17.9 kN/m^3 with a mean value of 15.5 kN/m^3.

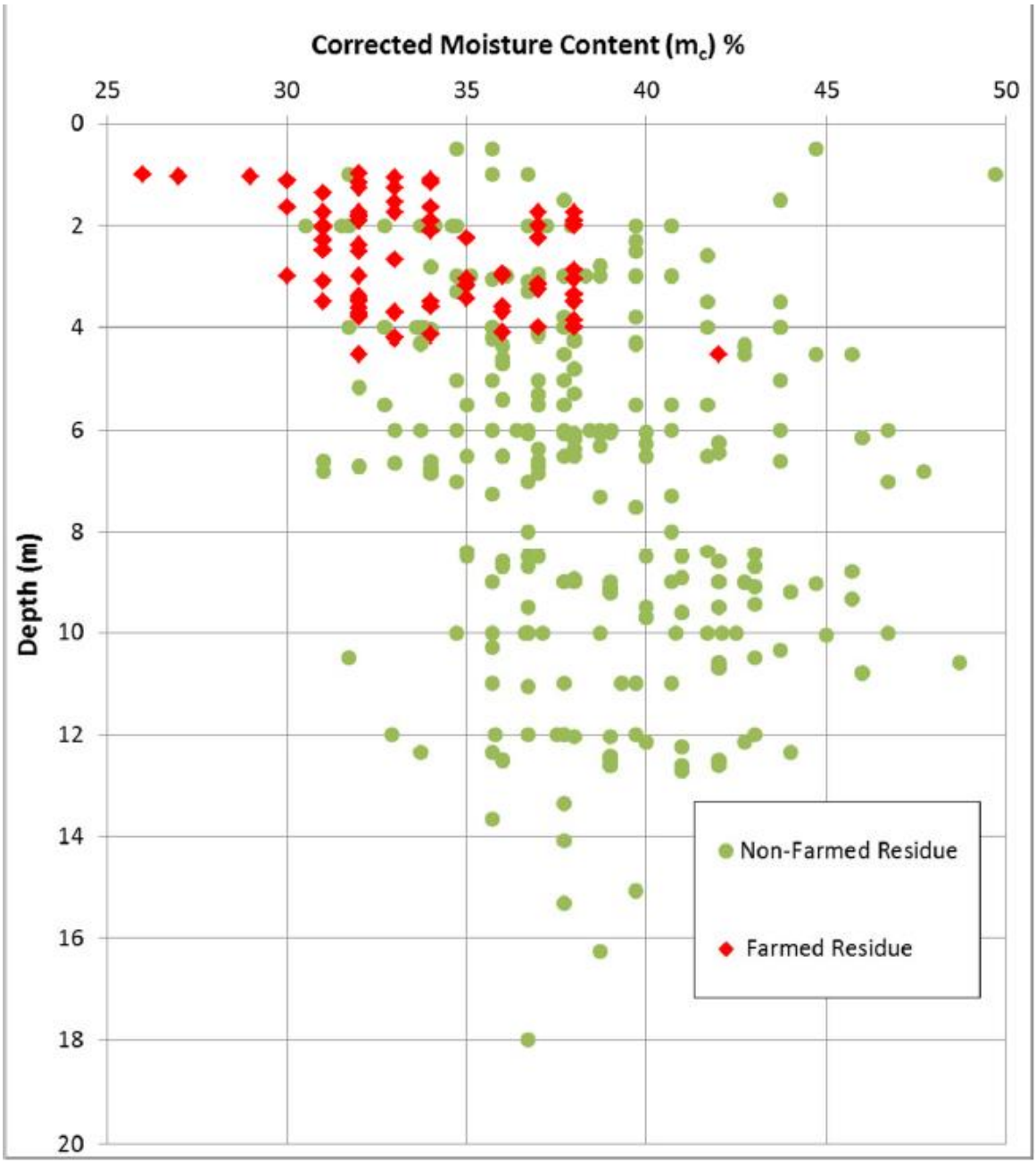
On average y_d testing indicates that farmed residue has higher y_d (16.8 kN/m^3) than non farmed residue (15.5 kN/m^3). These results suggest farming operations lead to an approximately 8.4% increase in dry density. The density versus depth profile is shown below.



e) The specific gravity or particle density for bauxte residue varies between 3.39 and 3.65 with an average of 3.48. These high values reflect the amount of iron in the residue.

(5) Water Content

The moisture content m_c within the farmed residue is generally lower with values from 26 to 38% while the values within the lower non-farmed residue ranged from between 31 and 49%. In both data sets there does not appear to be any relationship between m_c and depth. The graph below presents these results indicating the m_c with depth as well as identifying whether testing was carried out on farmed or non-farmed residue.



(6) Degree of Compaction

In general the bulk density y_b within the farmed residue ranged from between 21.5 to 24.5 kN/m^3 with a mean value of 22.5 kN/m^3. Within the lower non-farmed residue bulk density y_b ranged from 15.3 to 24.5 kN/m^3 with a mean value of 21.5 kN/m^3.

In general the dry density y_d within the farmed residue ranged from between 15.6 to 18.5 kN/m^3 with a mean value of 16.8 kN/m^3. Within the lower non-farmed residue, dry density y_d ranged from 7.9 to 17.9 kN/m^3 with a mean value of 15.5 kN/m^3.

On average y_d testing indicates that farmed residue have have higher y_d (16.8 kN/m^3) than non farmed residue (15.5 kN/m^3). These results suggest farming operations can lead to an approximately 8.4% increase in dry density.
The above indicates the degree of increased compaction within the bauxite residue that is occurring with the introduction of mud farming techniques.

(7) Shear Strength

a) In general, the triaxial data with depth presents undrained shear strength values at peak strains of between approximately 23 to 300 kPa with an aveage of approximately 90 kPa. For mud farmed residues the values are between approximately 37 and 300 kPa were obtained with an average of 138 kPa.

b) Undrained shear strength has been correlated with moisture content. Based on the relationship established an adopted boundard between farmed and the lower non-farmed residue has been established at 110 kPa and approximately 35% moisture content. Derived shear strengths for non-farmed residue can be taken as between 11 kPa and up to approximately 110 kPa. The correlation between undrained shear strength and moisture content is illustrated below.

(8) Angle of Friction

The lower bound undrained shear strength in the bauxite residue is equivalent to a friction angle of 13 degrees and a cohesion of 35 kPa. For the drained condition the angle of friction is 32 degrees and effective cohesion of zero.

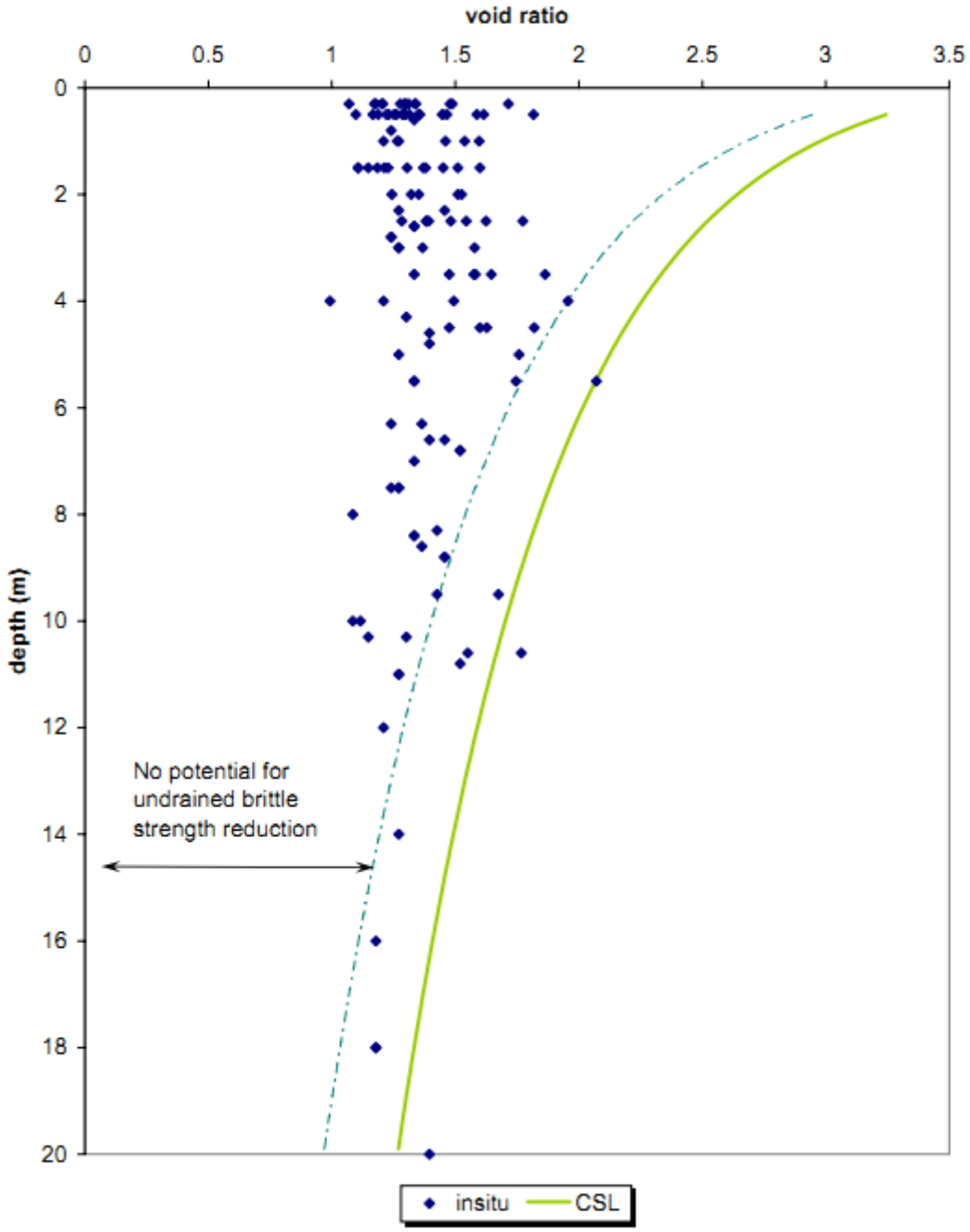
(9) Permeability

In 2014, three residue core samples were tested by the Golder Lab in Atlanta using a Flexible Wall Triazial Permeameter conducted to ASTM D 5084 , Method C, Falling Head with Increasing Tail Water Pressure. The results, shown below, indicate an average permeability of 1.9E-08 m/s permeability.

Sample Ref.	Dia. (mm)	Height (mm)	Bulk Density (Mg/m^3)	Initial Moisture Content (%)	Final Moisture Content (%)	Initial Dry Density (Mg/m^3)	Final Dry Density (Mg/m^3	Coeff. Of Permeability (k_v) at 20°C (m/s)
Golder Lab. Testing								
1	101	133	2.200	26.9	27.7	1.733	1.723	3.7×10^{-8}
2	99	127	2.200	26.5	26.6	1.739	1.737	1.1×10^{-8}
3	99	130	2.200	27.6	27.5	1.724	1.725	8.5×10^{-9}
BHP Lab. Testing								
4	102	130	2.225	26.6	N/A [3]	1.758	N/A [3]	N/A [3]
5	100	128	2.202	28.0	N/A [3]	1.720	N/A [3]	N/A [3]
6	102	129	2.115	28.1	N/A [3]	1.651	N/A [3]	N/A [3]
AVERAGES			2.190 [1]	27.3 [1]		1.721 [1]		1.9×10^{-8} [2]

(10) Void Ratio

The issue of post-peak reduction in undrained strength was evaluated in the laboratory tests, showing the potential brittle reduction. The state parameter of the bauxite residue for no brittle strength reduction, which is the mechanism that can lead to liquefaction drivenflow slides, is $\psi < -0.3$. This state parameter has been used to define a limiting void ratio profile to avoid brittle strength reduction and is shown on the Figure below. Most of the residue is denser than this limiting void ratio and therefore not prone to liquefaction.



(11) Compressibilty

The coefficient of volume compressibility for the bauxite residues determined from the consolidation testwork indicate a range of 0.3m^2/MN to 1.0m^2/MN over a stress range of 100kPa to 600kPa.

(12) Consolidation

The coefficient of consolidation is generally in the range of 5 m^2/year to 30 m^2/year. The coefficient of consolidation from the consolidation drained tests were very low between 0.6 and 2.5 m^2/year.

3.3.2 Process Sand

Process sand is deposited in the interior of the BRDA and has no geotechnical function with respect to stability. Therefore the data on process sand is limited to the following:

(1) Minerology

The filter sand consists of an agglomerate of particles of less than a 1000 microns. The agglomerates comprise clusters of mineral grains which are generally less than 4 microns. The mineral grains are amorphous or very poorly crystalline. The bulk (90% to 95%) of the sample comprises red brown friable particles of oxides, hydrated oxides and oxi-hydroxides such as boehmite, goethite and gibbsite which are sub rounded and readily crushed between the fingers.

(2) Particle Size Distribution

The particle size distribution for the process sand places it primarily in the poorly graded medium sand classification, as tabulated below. 100% of the particles less than 2mm , circa 50% of the particles between 2mm and 425 microns and circa 96% of particles greater than 63 microns in diameter. Circa 25% of the particles are in the coarse sand range, circa 60% in the medium sand range and circa 15% in the fine sand or smaller particle range.

: Process Sand – Particle Size Distribution Testing Summary

Sieve Size (mm)	% Passing (Range of 5 Tests)
4	100
2	100
1	93 to 96
500 µm	59 to 72
425 µm	44 to 51
250 µm	11 to 16
125 µm	3 to 5
63 µm	2.3 to 3.9

(3) Bulk Density

The bulk density of process sand is approximately 1.36 tonnes /m^3.

3.4 Geochemical Characteristics and Behaviour of the Waste

3.4.1 Bauxite Residue

As outlined earlier bauxite residue is a finely divided suspension containing at least 17 different mineral compounds. It is a fine silt with a D50 less than 5 microns.

Bauxite residue at 58% solids is deposited in short campaigns building up a 0.4-0.5 m deep layer. Compression and furrowing via amphirol consolidates the residue to 70% solids.

The only property of concern in bauxite residue leachate is caustic soda. The bulk of the leachate is expressed upwards under self weight compaction accelerated by the amphirol action. The expressed leachate drains via furrows towards the low point at the perimeter. It passes through the porous rock fill embankment and cascades gently down to the lined perimeter channel at ground level. Wind and solar drying also play a role by evaporating water from the exposed residue surfaces. As bauxite residue has a low hydraulic conductivity of 10^{-6} to 10^{-7} cm/s only a small fraction of the expressed leachate drains vertically downward. Very little of this leachate enters the saline groundwater underneath as the Phase 1 extension is composite lined and the Phase 2 is fully composite lined.

The process of farming converts much of the residual caustic remaining after compaction to sodium carbonate. Thus when deposition of fresh bauxite residue ceases, the pH from leachate associated with the mature farmed bauxite residue will be close to 11.5. Modelling suggests an average 400:1 dilution of leachate by rainwater in a closed BRDA scenario. This dilution of a pre-carbonated leachate will result in a combined run-off of pH ~ 9.0 which will be suitable for direct discharge to the Estuary. The CRAMP submitted in 2018 to the Agency includes costing for treatment of this stream for a period of 5 years post closure to ensure pH < 9. It is anticipated that after this period no further treatment will be requird. However, since 2013 AAL have undertaken a study in conjunction with the Universtity of Limerick and the International Alumina Institute which desmonstrates that BRDA leachate of pH 11.5 can be reduced to pH 7 via passive wetlands in the event that 5 years post closure some treatment is required.

The BRDA location close to the tidal Shannon Estuary means that groundwater under the BRDA is predominantly brackish and thus not useful for extraction and treatment as potable water. Small quantities of high pH material entering this medium would be diluted and neutralised. Thus the strategic location of the BRDA ensures that leakage or seepage of BRDA leachate during either the operating phase or post closure will not have a significant impact on the receiving environment.

3.4.2 Process Sand

Process sand dewaters faster than bauxite residue due to its coarseness. It is used within the BRDA for road building/raising and its pH reduces due to regular exposure to rain.

3.4.3 Limestone Grits

Limestone grits disposed in the BRDA are coarse ranging in size from 1 millimetre to 100 millimetres. The slightly elevated pH associated with traces of slaked lime is masked by the higher pH associated with bauxite residue and sand. As such limestone grits material has no material impact on run-off or leachate quality.

3.4.4 Salt Cake

Salt cake is alkaline and is stored in a dedicated lined cell. Salt-cake does not impact on BRDA leachate quality.

3.5 Estimated Quantities of Extractive Waste to be Produced

A statement of the estimated total quantities of extractive waste to be produced during the operational phase is provided in Annual Environmental Reports submitted to the EPA. Engineering estimates of the total occupied and remaining capacity of the BRDA are also reported annually, as tabulated below for the past 5 years to the end of 2017.

Table 3.3 Estimated Capacity of BRDA

Period	Waste during period (t)	Accumulated waste (t)	Remaining capacity of BRDA (t)
2013	1,343,516	25,403,955	24,263,601
2014	1,464,224	26,868,179	27,475,746
2015	1,507,468	28,375,647	25,968,278
2016	1,514,519	29,890,166	24,269,311
2017	1,571,677	31,461,843	22,697,634

4. Description of Waste-Generating Operations & Treatment

Most of the information in this Section is also provided in the BRDA Operational, Safety and Maintenance Manual which is included as Appendix 5. The document contains all relevant data for the safe and effective operation, monitoring, long-term planning and aftercare of the BRDA and demonstrates that the BRDA operations are in accordance with:

- best management and safety practices
- environmental policies of RUSAL Aughinish Ltd and
- existing Licence conditions.

Information on the activities generating the waste and the composition of the waste has been included in Section 3 of this report.

4.1 Transport and Placement of Waste in the BRDA

There are written standard operating procedures (standard work methods) in place to deal with the operation of the BRDA.

The BRDA is operated by AAL sub-contractor Murphy International Ltd. who have overall responsibility for the collection, transportation, and placement of waste within the BRDA. The contract extends to resourcing and maintenance of all equipment including mobile plant which operate within the BRDA, including environmental control equipment for dust suppression.

There are 46 active locations where the residue can be discharged between both Phase 1 and Phase 2 BRDA. A discharge plan is prepared in advance and residue is directed to the target location defined by the plan. Automated angle valves are provided to facilitate this switching. The general principle is to spread a thin layer from the active discharge point as far as the perimeter. Once fresh bauxite residue reaches the perimeter rockfill embankment the discharge must be stopped and a new discharge point activated. In this manner the depth is built up layer by layer over the whole dome. Once the depth is close to the top of the rockfill embankment at the perimeter the lift capacity is effectively consumed and a new rockfill emnbankment must be constructed on top of the recently deposited residue.

Apart from bauxite residue all the other residues are trucked from the source locations in the plant in specified skips or dumpers to the BRDA laydown area close to the central discharge. All drivers are trained to ensure that only wastes permitted for disposal in the BRDA are transported in the designated skips. Any skips contaminated with other wastes are not accepted by the driver.

All trucked residues are transported within the BRDA on a network of internal access roads constructed to engineering standards. Trucked residues must be deposited on a layer of matured bauxite residue. Process sand may be deposited directly onto bauxite residue surfaces provided mechanical plant is confined to adjacent engineered designed and supervised access roads or the mobile plant is moving on a layer of compacted process sand.

4.2 Farming & Atmospheric Carbonation

The atmospheric carbonation of bauxite residue via mud farming is a condition of the IE Licence. The use of mud farming machinery, namely amphirolls, to densify and dry the bauxite residue layers (thereby reducing the footprint generation of the residue) and the use of that same machinery to enhance the exposure of the residue layers to atmospheric carbon dioxide (to reduce the liquid phase alkalinity in the bauxite residue and thereby reduce its pH to < 11.5) ensures that bauxite residue continues to remain a Non Hazardous residue.

Mud farming is a mechanical plant technique to further process and densify the bauxite residue layers following deposition in the BRDA and it also facilitates the atmospheric carbonation of the bauxite residue.

Archimedes Screw Tractors or commonly called amphirolls are used to plough and densify the bauxite residue by compressing the residue layer as well as increasing the residue surface area to enhance atmospheric drying. The weight and dynamic movement of the scrolls through the bauxite residue squeezes out residual fluid /water in the residue thereby densifying and increasing the solids contents. The drying of the residue is enhanced by the increase in surface area of the residue resulting from the ploughed furrows and ridges. The increase in the surface area of the bauxite residue thereby increases evaporation from the residue as well as increasing the contact area for the residual alkalinity in the residue layer with the atmospheric carbon dioxide - thereby carbonating and reducing the alkalinity and pH of the residue. In addition a low ground pressure bulldozer is used to grade out flat the ploughed furrowed surfaces of the residue prior to the placement of the next layer of fresh residue paste.

The strength, density and stability of bauxite residue increases with farming by amphirolling. In addition the pH of farmed bauxite residue is reduced to < 11.5.

5. Impact on Environment & Human Health

5.1 BRDA Stability Design and Monitoring

In compliance with the IE Licence (Schedule C7) Golder Associates are the Engineer of Record who carry out an annual review for the Bauxite Residue Disposal Area (BRDA). This stability evaluation summarises the monitoring results from Casagrande piezometers, inclinometers and extensometers, the visual inspection of the facilities and assesses the stability of the BRDA, the inner and outer perimeter walls forming the perimeter interceptor channel (PIC) and water storage ponds.

The BRDA is confirmed to be stable and performing in accordance with the design and shows no signs of distress.

Further information is available in the BRDA stability Appendix of the AER's submitted to the Agency.

5.2 Hydrogeology

The Phase 1 BRDA and most of the Phase 2 BRDA is underlain by a locally important aquifer. An eastern section half of the Phase 2 BRDA is underlain by a regionally important aquifer. The non-saline groundwater beneath the island is not believed to be connected to freshwater aquifers on the mainland and discharges as springs around the margins of the island.

The BRDA has been designed and operated to ensure that subsurface seepage from beneath the facility is minimised. Bauxite residue is pumped to the BRDA at approximately 58% solids and after settlement and consolidation the terminal solids content is approximately 70%. This difference is due to lateral and vertical seepage of pore waters. The interstitial pore waters within the residue at the time of disposal consist of caustic-contaminated wash water. The flux of water through the mass is very low because the hydraulic conductivity of the residue is low ranging from 10^{-6} to 10^{-7} cm/s allied to the fact that there is substantial retention of pore water. Some of this water exits as lateral seepage out of the internal side walls of the BRDA which discharge to the perimeter interceptor channel while some of it is vertical seepage out of the bottom which is not intercepted.

Regular groundwater monitoring of a network of monitoring wells in the BRDA is undertaken in accordance with Schedule C.6 of the IE licence and reported to the EPA every quarter. These paired monitoring wells are located around the perimeter of the BRDA in the glacial till layer and the limestone bedrock layer. To date no seepage has been detected via these observation wells.

5.3 Hydrology (Surface Water)

The bauxite residues deposited in the BRDA produce run-off with an alkaline pH. In addition, because of the fine-grained nature of the bauxite residue, particles can become entrained in surface water run-off posing a risk to adjacent watercourses.

The BRDA has been designed and is operated to ensure that all run-off from the facility is collected in the perimeter channel and treated before discharge. Subsurface seepage from beneath the facility is minimised through the use natural liner in the original construction and via composite liners in the two extensions since then.

Surface runoff from Phase 2 BRDA is collected in the perimeter channel around Phase 2 and pumped to Phase 1 perimeter channel. Surface run-off from Phase 1 BRDA plus transfer from Phase 2 is collected in the perimeter channel around Phase 1 BRDA. It is then pumped to the effluent treatment plant in the alumina refinery and or to the adjacent Storm Water Pond. The BRDA surface water management system is sized for a 1 in 200 year storm. This ensures that storm water can be removed from the BRDA perimeter channels to the effluent treatment plant for processing and discharge to the Shannon or into the Storm Water Pond for temporary storage.

5.4 Dust

The surfaces of deposited bauxite residue could be susceptible to dust blow if not managed properly.

Dust is controlled primarily utilising an automated network of fixed-point water sprinklers spaced evenly throughout both Phase 1 and Phase 2 BRDA. This system of sprinklers is supplied with neutralised and clarified effluent at a flowrate of up to 650 m3/hr and a supply pressure of 1180 kPa. There are a number of seperate rows of each with up to 15 fixed point sprinkler heads. When pressurised the sprinkler heads rotate to deliver 360 degree water coverage. Each sprinkler gun provides 50 m^3/hr to the BRDA surface per cycle. This means that the full BRDA area can be automatically and remotely sprinkled in just over 3 hours.

Mobile water bowser sprinkling of haul roads leading to the BRDA and haul roads within the BRDA is carried out in dry weather throughout the year. Where necessary these water bowsers equipped with rain guns can supplement the fixed point water sprinklers. If required temporary roads are constructed within the BRDA to access areas requiring additional sprinkling.

The introduction of farming has reduced the susceptibility to dusting through at least 2 mechanisms:

- In fresh bauxite residue the area exposed to wind is reduced due to the furrowing of the surface
- Carbonation of the surface makes the residue surface more susceptible to dusting. Harrowing and ploughing of the surface breaks up this carbonated crust and buries it in the residue

5.5 Odour

There is no odour associated with those wastes disposed in the BRDA.

5.6 Noise and Vibration

Normal operations and activities in the BRDA do not jeopardise the plants permitted day-time noise limit of 55 dB, evening time limit of 50 dB and night-time noise limit of 45 dB as specified in Schedule B.4 of the IE Licence. Compliance is verified through spot checks and completion of annual noise surveys at Noise-Sensitive Receptors (NSL's) agreed with the EPA.

5.7 Accidents & their Consequences

From a health and safety perspective the activities of highest risk are:

- Driving and discharging dumper trucks on BRDA internal roads
- Operating equipment on soft bauxite residue

Method statements, risk assessments and routine training and observation are key to achieving zero accidents in the BRDA.

From an environmental perspective, the most likely worst case scenario is over-topping of the BRDA perimeter channel with alkaline storm water or bauxite residue slurry. In such a 'BRDA Containment Failure' scenario, the land between the outer embankment of the BRDA and the OPW sea wall would be contaminated with alkaline bauxite residue and/or water. In 2014 a penstock valve was installed, the closure of which will contain any spillage within that land until it could be recovered back to the plant.

In 2018, the ELRA (Environment Liabilities Risk Assessment) was submitted to and approved by the Agency. This indicated the the worst case scenario relates to a spillage of fuel from a tanker travelling within the refinery road network. The worst case scenario does not relate to the BRDA.

6. Control & Monitoring Procedures

6.1 Stability Monitoring

In compliance with the IE Licence (Schedule C7) Golder Associates are the Engineer of Record who carry out an annual review for the BRDA. This overall geotechnical stability evaluation of the BRDA summarises the monitoring results from Casagrande piezometers, inclinometers and extensometers, the visual inspection of the facilities and assesses the stability of the BRDA, the inner and outer perimeter walls forming the perimeter interceptor channel (PIC) and water storage ponds.

The BRDA is confirmed to be stable and performing in accordance with the design and shows no signs of distress.

Further information is available in the BRDA stability Appendix of the AER's submitted to the Agency.

6.2 Environmental Monitoring

AAL undertakes extensive monitoring of environmental quality (air, water, groundwater, dust and noise) in the vicinity of both the plant and BRDA in accordance with the requirements of our IE Licence, as tabulated below.

Table 6.1 Environmental Monitoring in the BRDA

Environmental Media	Monitoring Location	Analysis Undertaken	Frequency
Surface Water	OPW Channel, Mangans Lough, Phase 2 West Robertstown Gate	pH, Conductivity, Soda	Monthly
Groundwater	BRDA Observation Wells (OW's)	pH, Conductivity, Total Alkalinity, Fluoride, Chloride, Soda, Heavy Metals	Quarterly
Air – Fugitive Dust	Dust Gauges at perimeter of BRDA	Dust Deposition	Monthly
Noise	Boundary Locations around BRDA: North Shore (B5), East of East Ridge (B4)	Sound Pressure Level, L_{AEQ}, L_{A10}, L_{A90}	Annually
Waste	Red mud, Sand, Salt Cake, Leachate	pH, Dry Matter, Alkalinity, Chloride, Fluoride, Soda, Metals	Quarterly

In addition to the above, AAL maintain a weather station between the plant and the BRDA for measurement of wind speed, direction and temperature. This data is fed back to the plant Process Information (PI) System.

Monitoring of surface water quality and groundwater quality in the vicinity of the BRDA will continue for a period of up to 30 years post closure.

7. Closure, Rehabilitation and Aftercare Plan

The most recent Closure, Rehabilitation and Aftercare Management Plan (CRAMP) was submitted to the EPA in 2018.

AAL has proposed that the BRDA will be re-vegetated directly, as opposed to capping with an engineered layer of topsoil. This is based upon many years of research, as published at the ICSOBA 2017 conference entitled 'Bauxite Residue Disposal Area Rehabilitation' authored by K. McMahon, refer to Appendix 6.

Engineering proposals to address the drainage, seepage, control of storm water and surface run-off from the BRDA have been investigated and designed by AAL's consultant Golder Associates.

7.1 Closure and Restoration Programme

Following closure, the BRDA will be rehabilitated to ensure physical and chemical stabilisation of the bauxite residue and other process residues deposited in the BRDA. Restoration of the BRDA including side slope restoration will be carried out on a phased basis. Refer to Section 7.3 of the CRAMP submitted in 2018.

7.2 Interim Restoration

In 2013 Phase 1 BRDA capping works were undertaken to improve drainage and visual impact of the area. Preliminary works for the main project involved the excavation and removal of the vegetation and compost/topsoil from the side-slopes of the rock fill stage raises and the bauxite residue benches on the north and west faces of the Phase 1 BRDA. The Civil Works and Landscaping involved the construction of capping containment works on Stages 1 - 4 and Stages 6 – 9 of the north and west faces of the Phase 1 BDRA. The capping comprised of a separation geotextile places above the levelled and graded bauxite residue benched, overlain by a minimum 300mm thick layer of rock fill excavated from the rock fill stage raise directly above and in turn overlain by a second separation geotextile. Subsoil and topsoil were placed above the separation geotextile and the embankment was landscaped in accordance with the Brady Shipman Martin Ltd. (BMS) Landscaping Technical Specification which included tree planting. The total area for revegetation was 36,870m^2 in which over 4,000 trees and scrubs of varying species were planted. Many plant species have also naturally developed on the side slopes of the BRDA.

Drainage channels were excavated at the toe and crest of the stage raise embankments which in turn connected to larger collector drains installed at 100m intervals radially around the BRDA, from Stage 9 to the Perimeter Interceptor Channel (PIC) at Stage 0. The wider stage 5 bauxite residue bench was treated and landscaped in accordance with an AAL specification following the installation of toe and crest drains. Further works included in the project included landscaping of the Phase 1 and 2 Storage compound areas.

7.3 Timeframe

Table 5 shows the proposed fill dates for each phase of the BRDA. It is estimated that the entire BRDA will reach capacity by approximately 2031.

Table 7.1 Timing of Stages in the BRDA

Date	Phase 2	Phase 1
2018	Stage 3	Stage 9
2019	Stage 3	Stage 10
2020	Stage 4	Stage 10
2021	Stage 4	Stage 10
2022	Stage 5	Stage 10
2023	Stage 5	Stage 10
2024	Stage 6	Stage 10
2025	Stage 6	Stage 10
2026	Stage 7	Phase 1 Extension full
2027	Stage 7	Restore Phase 1
2028	Stage 8	
2029	Stage 9	
2030	Stage 10	
2031	Phase 2 Extension full	

7.4 Aftercare Monitoring and Management

Refer to Section 7.4 of the CRAMP submitted to the Agency in 2018.

Success of surface re-vegetation (which will be critical in meeting requirements for control of fugitive dust and valuable in the limitation of subsurface seepage and the maintenance of geotechnical stability) will be measured on the basis of vegetation and soil biological surveys. These surveys will be conducted annually until Year 5 upon which time it is anticipated that the re-vegetation programme will be deemed successful. Should the five-year objective not be met, AAL will identify the measures that it will undertake to improve the performance of the cover.

At closure, the water sprinkler system will continue for a limited period, particularly throughout any periods of leaching and weathering, until surface rehabilitation by a vegetated surface cover is established. The long-term suppression of fugitive dust will be achieved by installing a vegetation cover with sufficient density to retain the residue material.

Water treatment will no longer be considered necessary when the pH in the perimeter channel is maintained at less than or equal to pH 9 with a Total Suspended Solids (TSS) of less than 50 mg/l for 90% of the samples taken over a 12-month period. Following attainment of water quality objectives for a one-year period without treatment, the water management system will be decommissioned. The perimeter channel and the SWP can then be breached (with spillway and sluice constructions) to allow for direct discharge to the Shannon Estuary via the Robertstown River. It is anticipated that this can be achieved within five years post-closure.

Monitoring of surface water quality and groundwater quality in the vicinity of the BRDA will continue for a period of up to 30 years post closure.

To monitor geotechnical stability, for five years after the closure of the BRDA, AAL will conduct periodic monitoring of subsoil moisture, to demonstrate that the suction head for the upper subsoil layers is being maintained, or reduced, as a result of the rehabilitation measures.

7.5 Final Land Use

The preferred land-use option for the BRDA, based on current knowledge of the chemistry and biology of the sown grassland cover, is to develop the area for nature conservation and amenity. A section of AAL land to the north of the BRDA has already been developed as a Bird Sanctuary, so the development of a nature conservation area is in keeping with AAL land conservation practices. The bird sanctuary management has been featured and reported on by organisations such as the Irish Wildbird Conservancy since its development in 1981.

Lands adjacent to the AAL facility are subject to EU and national environmental designations and the sensitivity of these environmental receptors, particularly in the key areas of surface and groundwater quality, have been taken into account in the design of the BRDA restoration and aftercare process.

8. Measures for Prevention of Water Status Deterioration

The BRDA has been designed and is operated to ensure that subsurface seepage from and groundwater contamination beneath the facility is minimised. Both the extension to the Phase 1 BRDA and the Phase 2 BRDA are composite-lined to prevent groundwater contamination. Any high-pH groundwater is recovered groundwater and treated in the site effluent treatment plant. This treatment plant will remain in operation for an expected period of five years post-closure after successful attainment of the water quality criteria is met, i.e. when pH of recovered water is less than 9.

The BRDA has been designed and is operated to ensure that run-off and leachate from the facility is collected and pumped back to the plant effluent treatment plant for treatment prior to discharge. This will continue in operation for five years post closure.

AAL undertakes extensive monitoring of environmental quality (air, water, groundwater, dust and noise) in the vicinity of both the plant and BRDA in accordance with the requirements of the IE Licence This monitoring is undertaken by qualified and experienced Environmental Technicians Monitoring of surface water quality and groundwater quality in the vicinity of the BRDA will continue for a period of up to 30 years post closure.

Table 8.1 Current Environmental Monitoring in the BRDA

Environmental Media	Monitoring Location	Analysis Undertaken	Frequency
Surface Water	OPW Channel Mangans Lough Phase 2 West Robertstown Gate	pH, Conductivity, Soda	Monthly
Groundwater	BRDA Observation Wells (OW's)	pH, Conductivity, Total Alkalinity, Fluoride, Chloride, Soda, Heavy Metals	Quarterly
Air – Fugitive Dust	Dust Gauges at perimeter of BRDA	Dust Deposition	Monthly
Noise	Boundary Locations around BRDA: North Shore (B5), East of East Ridge (B4)	Sound Pressure Level, L_{AEQ}, L_{A10}, L_{A90}	Annually
Waste	Red Mud, Sand, Salt Cake, Leachate	pH, Dry Matter, Alkalinity, Chloride, Fluoride, Soda, Metals	Quarterly

9. Survey of Land Condition

Site investigation reports by Golder Associates (for both the Phase 1 and Phase 2 BRDA were previously submitted to the Agency in June 2005 as part of the IPPC licence application to develop the Phase 2 BRDA and raise the Phase 1 BRDA. These reports summarise all the previous reports as follows:

- A considerable amount of site investigation work was carried out beneath the footprint of the Phase 1 and Phase 1 extension together with an area to the south which was the original alignment for the Phase 1 BRDA. The original alignment extended to the northern flank of the Poulaweala Creek. During the period between January 1971 and January 1973 Soil Mechanics Ltd (SML) carried out a site investigation as part of the feasibility study for the bauxite beneficiation plant at Aughinish. Further site investigation work was undertaken by SML between 1973 and 1975. The site work was undertaken to investigate the suitability of the foundation materials and potential construction materials in the Phase 1 area. A hydrogeological study of the area was carried out by Ercon in 1974.

- The next phase of site investigation work was carried out in the late 1980s by Site Investigation Ltd (SIL) in 1987 and 1988 Delft Geotechnics and Ove Arup in 1988 , University College of Galway (UCG) in 1989 (Reference 9) and Irish Geotechnical Services Ltd (IGSL) in 1989 . The work was undertaken to investigate the engineering properties of the bauxite residue and the suitability of the foundation materials and borrow materials in the Phase 1 extension area.

- Further investigation work was undertaken by UCG and Geocon in 1993 relating to the engineering properties of the bauxite residue and suitability of the estuarine and glacial till as construction materials for the Phase 1 extension.

- In 2002, a site investigation was carried out by Glover Site Investigations and Lankelma to determine the undrained shear strength of the bauxite residue in order to compare these values with the design criteria. Further hydrogeological work was undertaken by URS in 2003

- Golder Associates undertook their own site investigation of the Phase 1 BRDA using Fugro Engineer Services Ltd (Fugro) in the period between January 26th and February 6th 2004 and a geotechnical engineer from Golder was present during that period. The site work consisted of;
    - Cone Penetration Test (CPT);
    - Dissipation testing;
    - Mostap undisturbed sampling;
    - In situ shear vane testing;
    - Installation of vibrating wire piezometers.

- A geotechnical investigation for the Phase 2 BRDA was carried out by Golder between 29 January and 11 February 2004. In total, 43 trial pits were excavated, 11 boreholes drilled and 5 piezometers installed. The majority of the trial pits were excavated in potential glacial till borrow areas whilst the boreholes were located on or close to the dam alignment where estuarine soils were likely to be encountered.

- In addition Golder Associates have undertaken routine CPT testing of the Phase 1 BRDA in 2006, 2010, 2014 and will be completd in 2018.

10. Map

A map and aerial photograph of the BRDA showing the boundary and limits of extractions are included in Appendix 6.

Appendix 1A

1.3. RUSAL Aughinish Accident Prevention Policy

RUSAL Aughinish considers the prevention of accidents and ill health to be as important as any other aspect of its business. The company seeks to protect human and physical resources and the environment by the elimination or reduction of hazards and risks and by the provision of safe plant and machinery, safe access and egress from place of work, safe systems of work and management of change.

RUSAL Aughinish recognises its responsibility for providing its employees with a safe and healthy working environment and is committed to meeting its obligations under the Safety, Health and Welfare at Work Act, 2005 and all associated regulations. This includes all relevant Occupational Safety and Health and Dangerous Substances legislation and associated codes of practice administered and enforced in whole or part by the Health and Safety Authority.

RUSAL Aughinish operates under an Industrial Emissions Licence which specifies its obligations in regard to Accident Prevention and Emergency Response including compliance requirements with regard to the BRDA categorisation as a Category A waste facility. This covers all its operations (including the Bauxite Residue Disposal Area) all materials, process streams and emissions.

The Emergency Response Plan identifies the arrangements and responsibilities for handling emergency situations arising in the plant. This includes arrangements for liaison with external emergency services and Principal Response Agencies (PRAs) in the event of an emergency escalating to major proportions.

The Company achieves the above through implementation of:

- Safety Loss Control Evaluation System (ISRS)
- Emergency Response Plan
- ISO 14001 certified Environmental Management System
- Solas and QQI certified Training System
- ISO 9001 certified Quality Management System
- ISO 50001 certified Energy Management System.
- HSE Policy for RUSAL Alumina Division
- The Rusal Aughinish Ionising Radiation Protection Manual

Signed:

Seán Garland.

Seán Garland

Managing Director November, 2017

This Policy is issued under the authority of the Managing Director and is fully supported by the Board of Directors. It will be reviewed annually to ensure it remains up to date.

Appendix 1B

RUSAL Aughinish
Emergency Response Plan

Signed*:* _____

Rob McLean

Plant Emergency Co-ordinator

TABLE OF CONTENTS PAGE

1.0 INTRODUCTION

1.1 Scope

This Plan is in compliance with the Safety, Health and Welfare at Work Act 2005. It covers emergencies and serious and imminent dangers ranging through:

- First Aid
- Fire Fighting
- Evacuation of employees and others present
- Contact with appropriate emergency services
- The designation of employees to implement the emergency plan – emergency procedures

Emergencies or disasters are unexpected happenings with serious potential or consequences. We cannot normally predict when emergencies will occur or how they will develop. It is not practical therefore to prepare plans for all possible emergencies. What we can and must do is to put in place a standard framework plan to facilitate an effective response to any emergency which may occur. This framework plan (The Emergency Response Plan) will be backed up as far as is practical by more detailed procedures within each Department/Local for coping with the most likely emergencies which these Departments/Locals may encounter. These detailed procedures along with this Plan form the basis of the plant emergency response system.

1.2 Objective

The objective of emergency preparedness is loss prevention, with top priority always devoted to preservation of life.

The essential elements of the Emergency Response Plant are the Five Cs:

Communications, Command, Control, Co-ordination and

COMMON SENSE

1.3 Emergency Preparedness

Effective emergency response depends on: Planning, Training and Equipment. Primary planning is directed towards avoidance of emergencies, and secondary planning is directed towards responding effectively to emergencies if they occur.

Planning and training for emergency response must take place at plant level and within each Department or operating unit. At plant level, a major emergency exercise should be held with all external emergency services at least once every fifteen years or a period dictated by business needs. Each shift of each operating unit will hold an emergency drill at least once per year. Emergency evacuation drills will be carried out in all personnel buildings every six months.

Adequate emergency equipment must be available and maintained to cope with all emergencies which are considered likely to occur.

2.0 EMERGENCY RESPONSE PLAN

2.1 Purpose

In the event of an emergency at RUSAL Aughinish, it is necessary to have a safe and effective response in order to protect both life and property. This Emergency Response Plan together with Security, Fire and Safety Procedures are intended to achieve the above objective.

2.2 Scope

These procedures apply to all RUSAL Aughinish employees who may be working in the plant when an emergency occurs or who are called-in to assist with such an emergency, and to non-RUSAL Aughinish personnel who are in the plant during the emergency.

Emergencies covered by these procedures include all emergencies both on and off RUSAL Aughinish property which effect RUSAL Aughinish or its personnel in a significant way and external emergencies for which RUSAL Aughinish assistance may be required.

2.3 Emergency Definitions and Requirements

An emergency at RUSAL Aughinish is an unexpected happening requiring immediate action and which is beyond the resources of those employed in the immediate area. It may include any of the following conditions;

- Fire/Explosion
- Process Release
- Major Gas Leak
- Vapour Release
- Environmental Incidents
- Hazardous Material Spill
- BRDA Containment Failure
- Oil Spill
- Injury
- Bomb/Telephone Threat
- Shipping Accident
- Aircraft Accident
- Medical Emergency/Rescue
- Computer Emergency
- Severe Weather
- Other incidents or occurrences of a serious nature with real or potential damage to the environment

2.3.1 Degrees of Emergency

In 'A Framework for Major Emergency Management (2006)', emergencies are broadly divided into those which can be dealt with internally and those which require external emergency service involvement. External emergencies are defined as either 'Normal' or Major depending on the scale of the emergency and the extent of involvement of external agencies.

Emergencies at RUSAL Aughinish will be divided into two degrees or categories depending on their relative severity and the level of response necessary to achieve effective control.

These categories are:

1 Internal Emergency
2 External Emergency

(1) Internal Emergency

This is an emergency which in the opinion of the Security Control Officer is within the capability of RUSAL Aughinish internal resources and does not require involvement of external emergency services.

An Internal Emergency will be declared by the Security Control Officer and will require:

- The establishment of a Site Control Centre (at the scene of emergency*)*
- Informing those on the Level 1 Management List

And may require:

- Level 1 Management Call Out
- Establishment of a Communications Control Centre (at Area 79)

(2) External Emergency

This is an emergency, which not only requires RUSAL Aughinish internal resources to mitigate, but also requires external assistance from a Principal Response Agency (PRA) (i.e. An Garda Siochana, the Health Service Executive (HSE) and the Ambulance Service, Limerick County Council and the Fire Service)
and/or
assistance from other external agencies such as the Environmental Protection Agency (EPA), Inland Fisheries Ireland (IFI), Office of Public Works (OPW), National Parks

and Wildlife Service (NPWS), Shannon Foynes Port Authority, Shannon Estuary Anti-Pollution Team (SEA-PT) and the Health and Safety Authority (HSA).

In normal circumstances the On-duty Security Control Officer is responsible to declare the emergency and decide what external assistance is required based on the information available to him. In certain cases such as a BRDA containment failure, he may require assessment from plant specialists to determine if external services from the Principal Response Agencies are required.

An External Emergency will require:

- The establishment of a Site Control Centre
- The establishment of a Communications Control Centre
- Level 1 Management Call Out

And for a Major Emergency, may require:

- The establishment of a Management Information Centre
- Level 2 Management Call Out
- Further support from the Principal Response Agencies (PRAs) or other external agencies

An External Emergency can be a **Normal** or a **Major Emergency**.

A **Normal Emergency** involves response by one or more of the Principal Response Agency/Emergency Services.

A **Major Emergency** is defined as an event which, usually with little or no warning, causes or threatens death or injury, serious disruption of essential services or damage to property, the environment or infrastructure beyond the normal capabilities of the Principal Response Agency in the area in which the event occurs.

A Major Emergency requires the activation of specific additional procedures and the mobilisation of additional resources to ensure an effective, co-ordinated response.

A Major Emergency can only be declared by a Principal Response Agency

2.4 Aughinish Fire Brigade

The RUSAL Aughinish Fire Brigade, consisting of the Security Officer on duty and the volunteer fire crew members, will normally be the Emergency Response Team for all internal and external plant emergencies. The Aughinish Fire Brigade leader will normally be the Security Officer.

2.5 Site Control Centre

This is the location from where the direct mitigation and control of the incident is being directed. The following individuals will be located at the Site Control Centre:

- RUSAL Aughinish Fire Brigade Leader
- Facilitator of the affected area
- Local Authority Fire Chief (if external emergency)
- Volunteer Fire Crew Members

The Site Control Centre will normally be identified as the location of the Aughinish Fire Tender.

2.6 Site Controller

This is the individual in charge of all activities at the emergency site (Site Control Centre).

For Internal Emergencies involving fires and / or injuries, the Site Controller will be the RUSAL Aughinish Fire Brigade Leader (Security Officer).

For Internal Emergency incidents which do not involve fires or injuries, the Site Controller will be the Shift Plant Facilitator (SPF).

For all External Emergencies, involving fire and / or injuries, the Site Controller will normally be the RUSAL Aughinish Fire Brigade Leader until this role is handed over to the Local Authority Fire Chief or HSE Ambulance Service.

For all other External Emergencies (including BRDA containment failure), the Site Controller will be the Shift Plant Facilitator (SPF) until this role is handed over to a PRA (Principal Response Agency) or other external agency (e.g. Limerick County Council, EPA, An Garda Siochana).

In the event of handover to a PRA, each PRA will have a Controller of Operations and one of these will act as On-Site Co-ordinator. This will entail the PRA establishing a Command and Control system, including traffic and personnel management systems.

2.6.1 Internal Emergencies

Emergency Type		Site Controller
Internal Fire, Rescues, Traffic Injuries etc.	-	RUSAL Aughinish Fire Brigade Leader
Internal process emergency incidents Internal environmental incidents (e.g. spillages, leaks, releases)	-	Shift Plant Facilitator

2.6.2 External Emergencies

In the event that the emergency escalates to an external emergency, the Internal Site Controllers will hand over to the following:

Emergency Type		Site Controller
Major Fire	-	Limerick County Council Fire Chief
Shipping Emergency	-	Harbour Master
Fatalities, Criminal	-	Garda Chief
Multiple Casualties	-	HSE Chief Ambulance Officer
Process /BRDA/Environmental	-	Limerick County Council Environmental Engineer

In an External Emergency, the Site Controller will be the relevant PRA Controller of Operations who will act as On-Site Co-ordinator.

2.7 Plant Manager

He/She will co-ordinate the commitment of RUSAL Aughinish resources to the emergency site and will normally be located at the Communication Control Centre in Area 79.

2.8 Communications Control Centre

This will be used primarily to manage communications between emergency resources and will be located at a safe distance from the emergency area, where both emergency and operational functions can be co-ordinated. The Area 79 Gatehouse Building will normally be used for this purpose. The Area 76 Training Building is an alternative Communications Control Centre Location.

The following personnel, or a deputy acting on their behalf, will be located at this centre:

- Security Control Officer
- The Plant Manager (who will be in charge)
- Safety / Security Co-ordinator
- Others as required

Hi-visibility vests will be provided to key emergency personnel by this group to facilitate the identification of critical roles (e.g. Plant Manager, SPF, Fire Brigade Leader)

2.9 Management Information Centre (MIC)

In the event of a prolonged emergency, a Management Information Centre will be established by the Human Resources Department in either Area 73 or Area 79. This will be the briefing centre for management personnel not directly involved in responding to the emergency. This MIC will provide communication to the plant and to the next of kin as appropriate.

The following personnel will be located at the Management Information Centre as required:

- Administration Manager
- Human Resources & Community Affairs Manager
- Human Resources Department Co-ordinator
- Environment Co-ordinator
- ISIT Co-ordinator
- Others as required

2.9.1 Press Information Centre

In the event of a prolonged External Emergency, an information centre will be established specifically to communicate with external media organisations. This will be set up in the Training Room in Area 79 by the Human Resources & Community Affairs Manager. All press and media enquires will be directed to this centre.

Press releases will be agreed between the Human Resources and Community Affairs Manager (or a Manager authorised to act on his behalf) and the Lead PRA's Media Liaison Officer.
No information on the emergency will be released to the press except through the Press Information Centre.

2.10 Declaring and Ending an Emergency

For an Internal Emergency, the emergency initiator will be the on duty Security Officer (also the RUSAL Aughinish Fire Brigade Leader) who will also decide on the degree of emergency. The Plant Manager will review the degree of emergency as soon as he/she arrives on the scene and will be the authority for downgrading the degree of emergency and for declaring the emergency over.

For an External Emergency, the Lead PRA On-site Co-ordinator will declare the emergency and will be the authority for declaring the emergency over in consultation with the other PRAs and the RUSAL Aughinish Plant Manager.

For a Major Emergency, the All-Clear for will be declared by the On-site Co-ordinator of the Lead PRA in consultation with the other Controllers of Operations at the site and the Local Co-ordination Group. The Local Co-ordination Group will consist of a representative of the lead PRA (e.g. LCC for a BRDA containment failure) and representative from the other 2 PRAs (HSE and Gardai) and would also include a Media Liaison Officer, an Information Management Officer and representatives from other agencies as appropriate (OPW, EPA).

2.11 Emergency Site Safety Officer

A member of the safety department will attend at every External Emergency. This individual will not be directly involved in the emergency response, but will be responsible for ensuring all emergency actions are conducted as safely as is practicable, given that the priority at emergencies must always be the preservation of life.

2.12 Emergency/ Incident Review

A review of each emergency will be held within 14 days. This review will be initiated by the Plant Manager and will be attended by representatives of personnel involved and responders. The objective of the review is to establish why the emergency happened, how to avoid it happening again, and evaluate the quality of the response.

2.13 Fire Marshals

Each building will appoint a Fire Marshal whose function is to ensure that buildings are evacuated in the event of fire alarm activation and to report any emergency as per Action Card No. 11 of this document.

2.14 First Aiders

RUSAL Aughinish have trained first aiders on each shift. All fire crew members are trained in first aid. Security Officers on each shift are trained to emergency medical first responder's level. First Aider actions at emergency are listed in Action Card No. 12 of this document.

2.15 Medical Staff

Occupational health nurses are on duty in the Medical Centre in Area 79 on normal dayshift from Monday to Friday and are responsible for treating all casualties or injured persons as per Action Card No. 10.

3.0 RESPONSIBILITIES

During an emergency, the Shift Plant Facilitator (SPF) and the RUSAL Aughinish Fire Brigade Leader work very closely together.

The broad responsibilities for the Fire Brigade Leader are to deal with the direct issues arising from the emergency, controlling the incident and maximising the welfare of people injured or affected by the event.

3.1 Responsibilities - Shift Plant Facilitator (SPF)

The SPF has a broader plant role.

For all types of emergencies, the following procedure will apply to the SPF:

3.1.1 Ensure that Security have activated the appropriate alarm and response plan (refer to Intranet / Safety / Safety Policy and Procedures).

3.1.2 Communicate the following to the RUSAL Aughinish Fire Brigade Leader (normally the Security Control Officer):

Personnel evacuation state – ie for fire alarm, evacuate; for process release, remain indoors

- Are all personnel in the affected area accounted for?
- Materials involved (including relevant Safety Data Sheet(s) (SDS))
- What is being done to secure affected area?
- Vessels which could or have failed.
- Other equipment which is being impacted by emergency.

3.1.3 Consider whether additional assistance is required. This may be either additional internal resources or external emergency service (such as PRA) support. External assistance must only be requested through the Security Control Officer or on his instructions.

3.1.4 Ensure that Operators have decided on the action to be taken which might range from isolation of the area or equipment involved, up to and including shutting down the area or plant entirely. Ensure that operators have identified, emergency equipment, isolation valves/switches and provide personnel to assist in control of emergency.

3.1.5 Contact the Plant Manager.

3.1.6 Provide assistance to the Fire Brigade Leader.
If the incident is a process emergency or a BRDA containment failure, the SPF will normally be the person in charge.

3.1.7 The SPF provides information on continually:

- Status of emergency
- If additional resources are needed
- Information on the materials involved (refer to SDS)

3.2 Responsibilities – RUSAL Aughinish Fire Brigade Leader

For all types of emergencies, the following procedure will apply to the RUSAL Aughinish Fire Brigade Leader:

3.2.1 Take the Fire Brigade, Ambulance or other appropriate equipment to the scene.

3.2.2 Ensure that the Site Controller and Site Control Centre are clearly identified. The Site Control Centre will normally be the location of the Aughinish Fire Tender.

3.2.3 A breathing apparatus control system will be established for all fire emergencies.

3.2.4 Co-ordinate with and assist the Limerick Fire Brigade on their arrival

3.2.5 Assign a person to escort the Fire Brigade, Ambulance and Gardai from the main gate to the incident scene.

3.2.6 Report injuries to the Communications Control Centre.

3.2.7 Make sure their team is accounted for and monitor their physical condition (heat, stress, injuries, etc.).

3.3 Responsibilities - Plant Manager

3.3.1 The Plant Manager or his / her delegate shall provide support to the SPF or Fire Brigade Leader who are dealing directly with the emergency.

3.3.2 The Communications Control Centre will normally be established at Area 79 (alternative Area 76). The Plant Manager (or his deputy) will take charge of this Control Centre and will be briefed by the RUSAL Aughinish Fire Brigade Leader.

3.3.3 The main external services we communicate with or may call to the site are:

Limerick Fire Brigade
Ambulance Service
An Garda Siochana
Limerick County Council
Health Service Executive
Shannon Foynes Port Authority (Harbour Master)
Shannon Estuary Anti-Pollution Team (SEA-PT)
Shannon Marine Rescue
Department of the Marine
Inland Fisheries Ireland
Environmental Protection Agency
Office of Public Works
National Parks and Wildlife Service
Health & Safety Authority
Eirgrid
Bord Gáis Networks, Shippers and End Users

The contact numbers are on the emergency phone list in the Security Dept, Area 79 and available on the Intranet / Safety / Safety Policy and Procedures/Emergency Procedures/Safety.

3.3.4 See Emergency Command System - Action Card No. 7.

3.3.5 The emergency area should be secured and traffic controlled by security or personnel detailed by the Plant Manager - this must include access and egress through all appropriate gates and entrances to the plant.

For Major Emergencies, the PRA will establish Command and Control systems for traffic and personnel.

3.3.6 Ensure through the Facilitator of the affected area that the area is evacuated and all personnel accounted for.

3.3.7 Continue to update the Management Information Centre, management staff, local authorities and others concerning the status as the emergency develops.

Action Card No. 1.

RUSAL Aughinish Alarm Signals

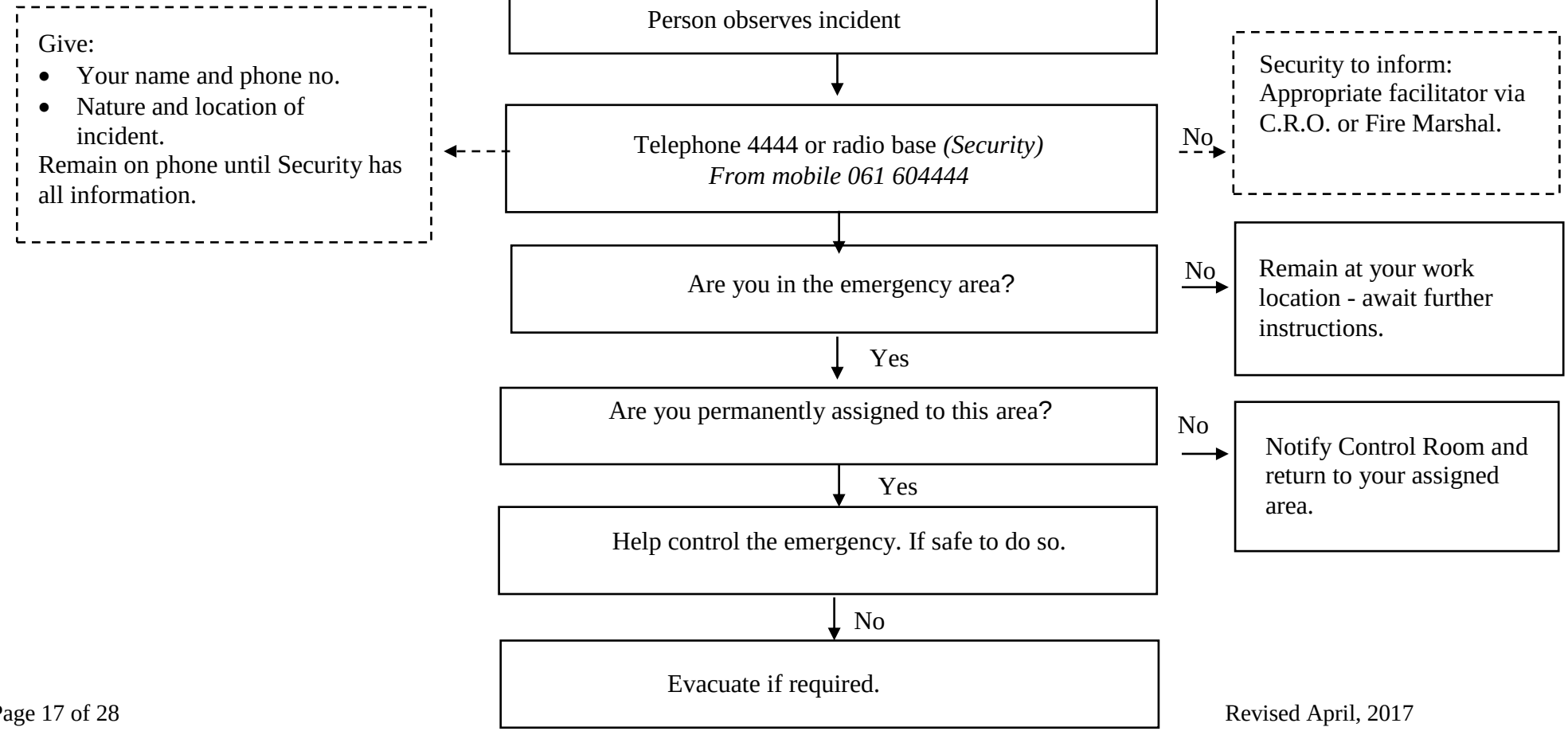
Alarm Type	Reason	Action	Activated By
Local fire bell ringing	Fire alert or emergency in building.		***1.*** Automatic fire alarm. ***2.*** Manual break glass units. ***3.*** If alarms fail shout ***'Fire'.***
Plant siren continuous signal. (for 15 mins max)	Plant / process emergency (e.g. major release)	**1.** Stay indoors or take cover. **2.** Await instructions from Fire Marshals.	Sec. control off. *(where possible confirm cause with Shift Plant Facilitator).* (stays in place until **Emergency** all clear is sounded).
Plant siren intermittent signal (for 10 mins max)	Emergency All Clear	Emergency All Clear	Security Control Officer

Fire Crew Call Out via the emergency radios in the control rooms

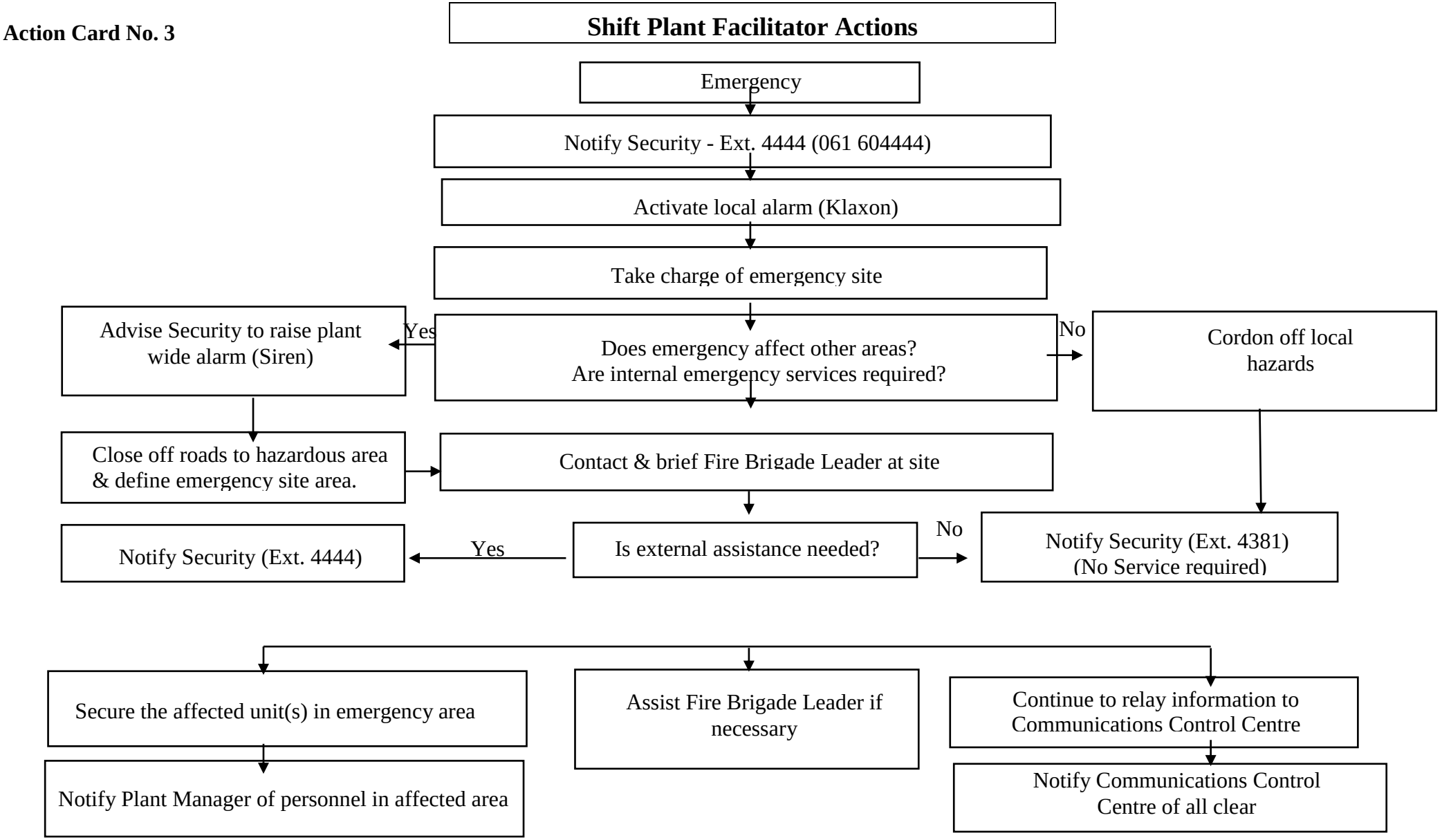
Action Card No. 2.

Emergency Reporting Process

(All Personnel)



Action Card No. 3



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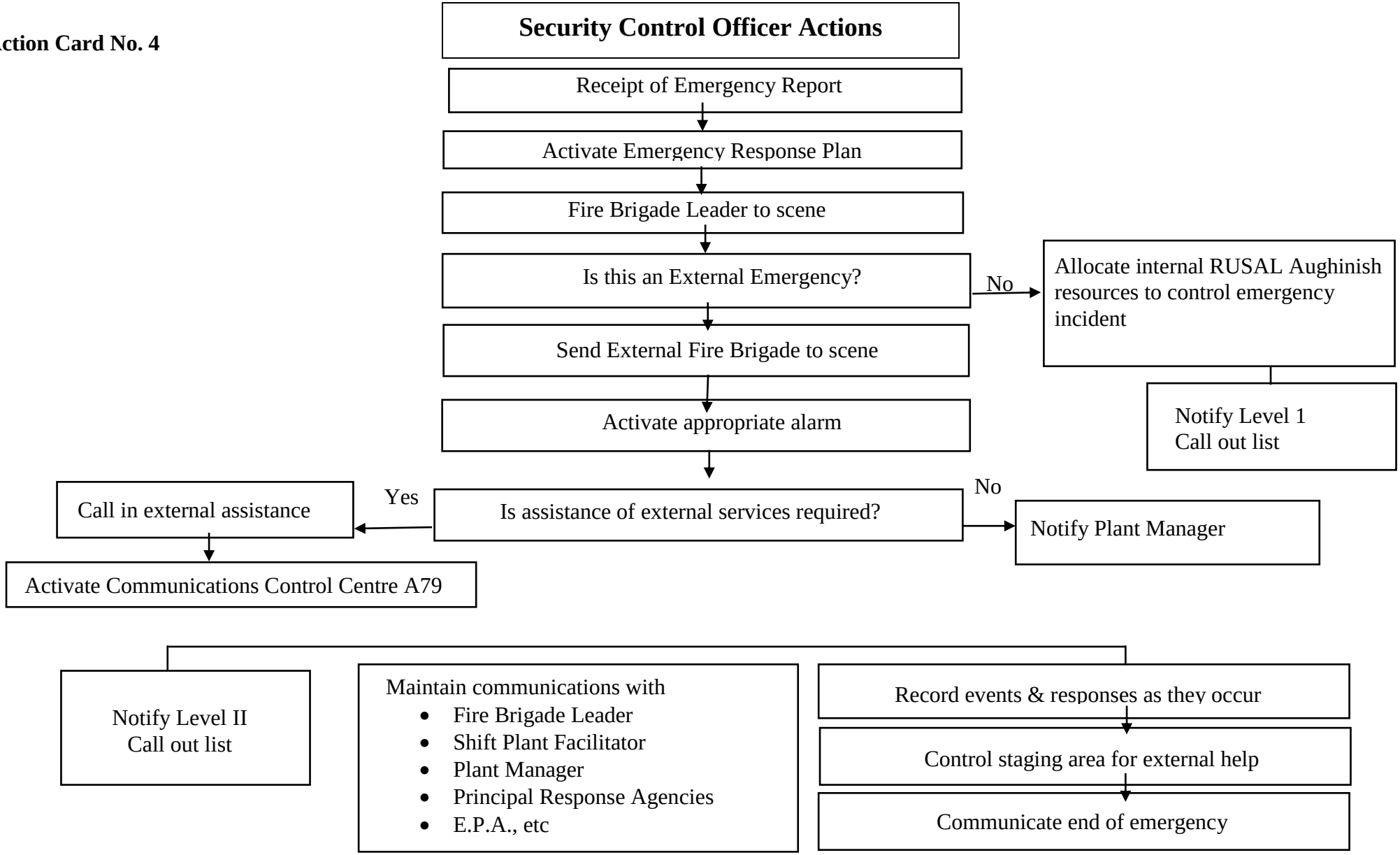
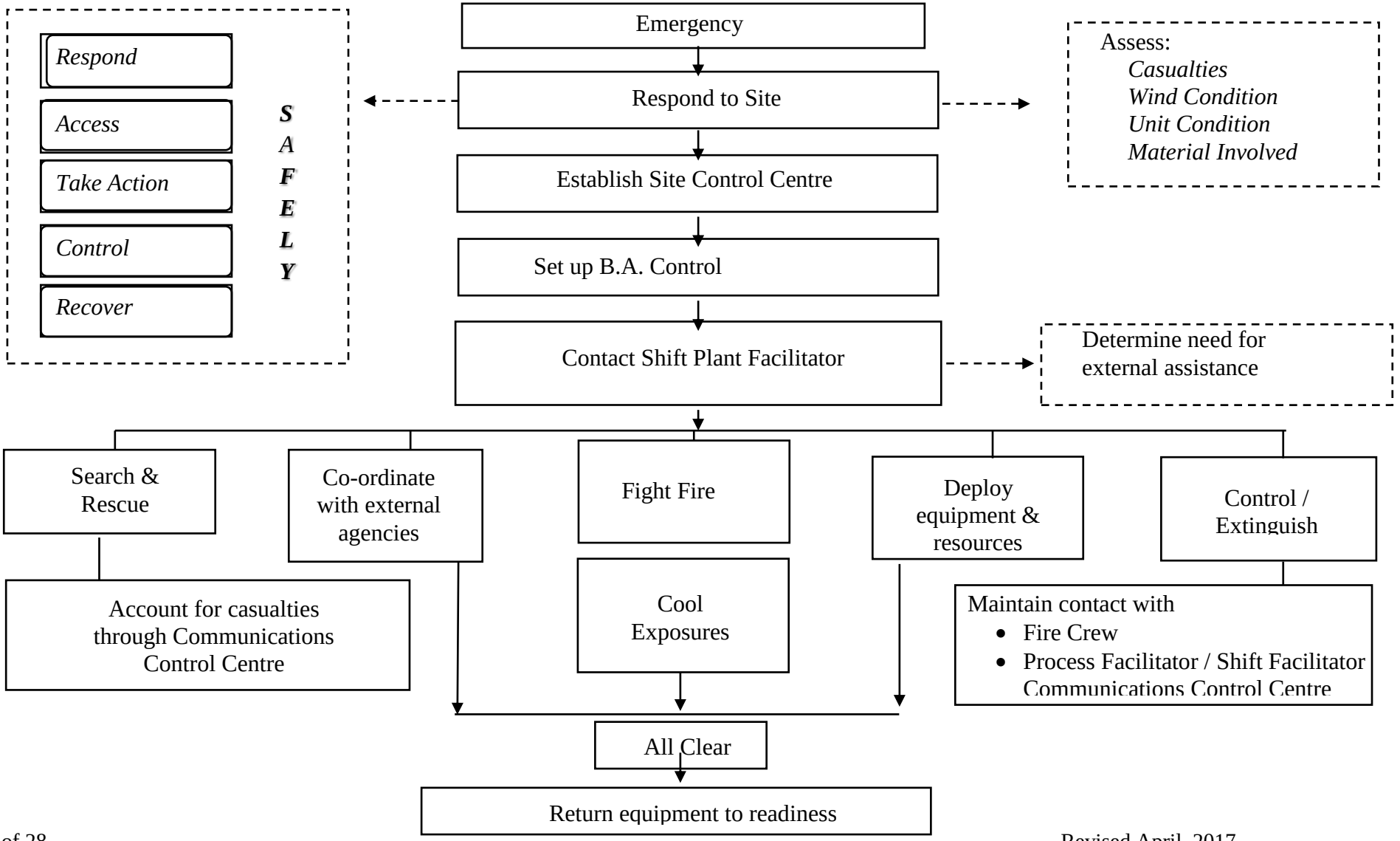


Action Card No. 5

RUSAL Aughinish Fire Brigade Leader Actions



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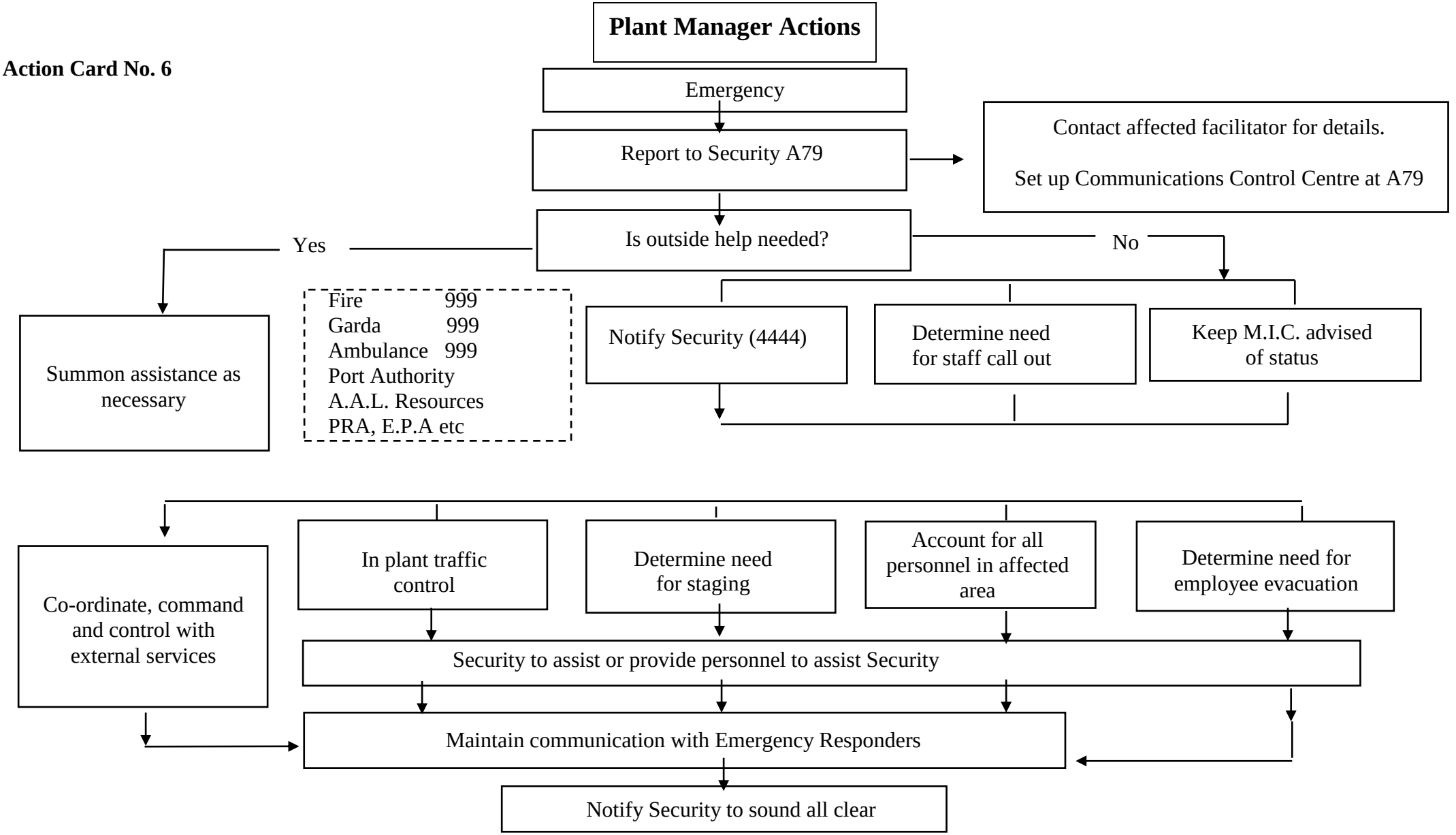
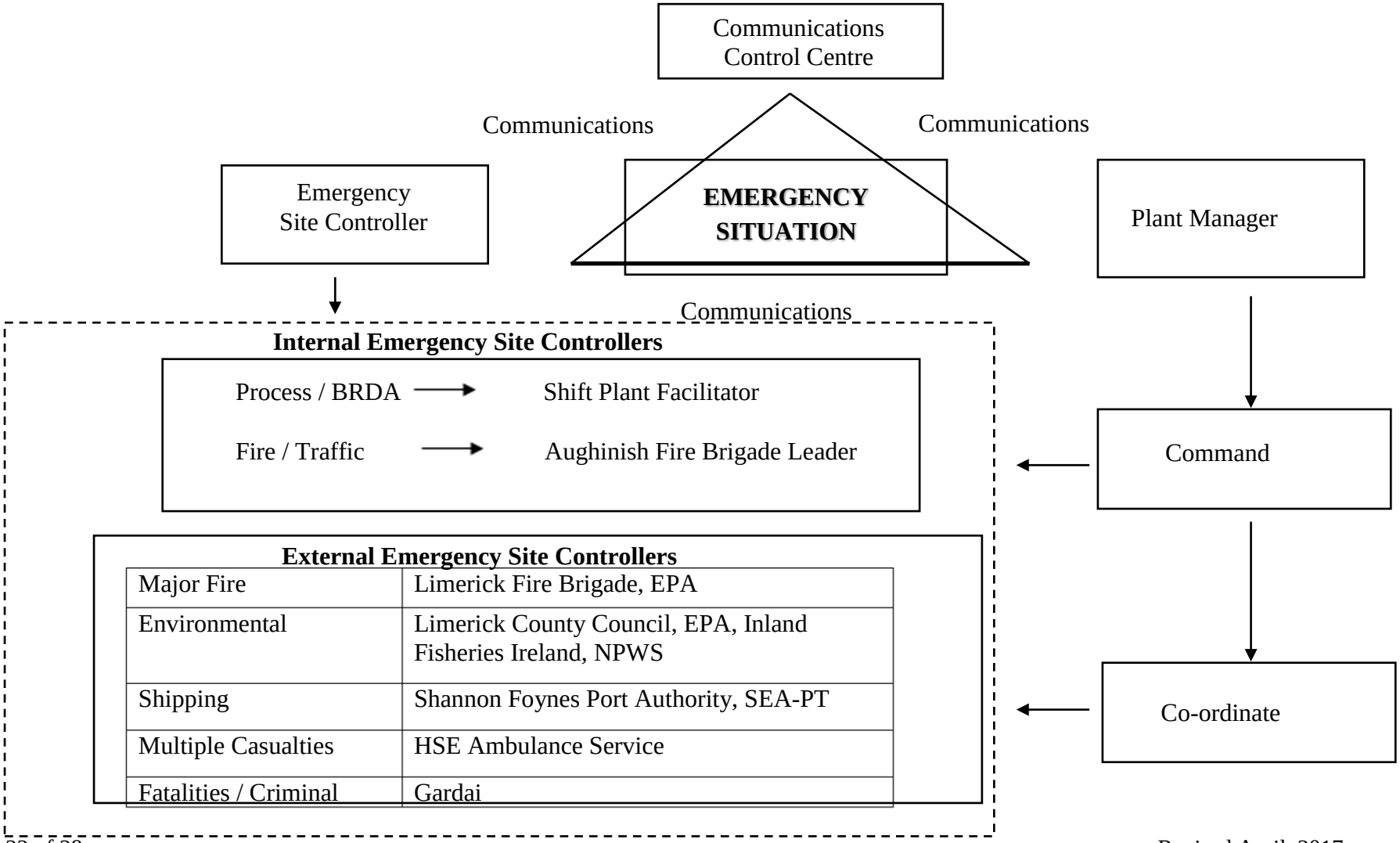
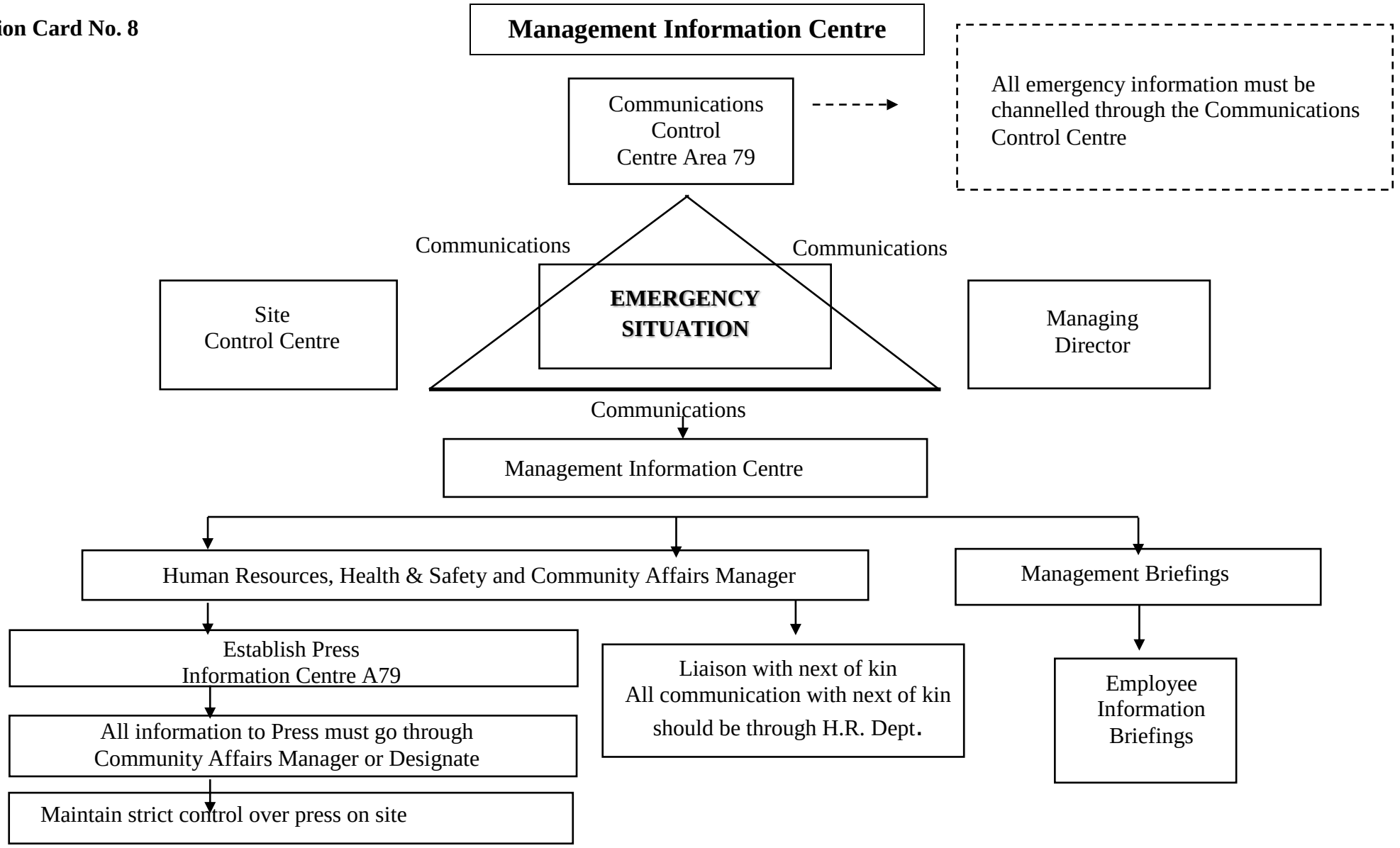


Action Card No. 7

Emergency Command System

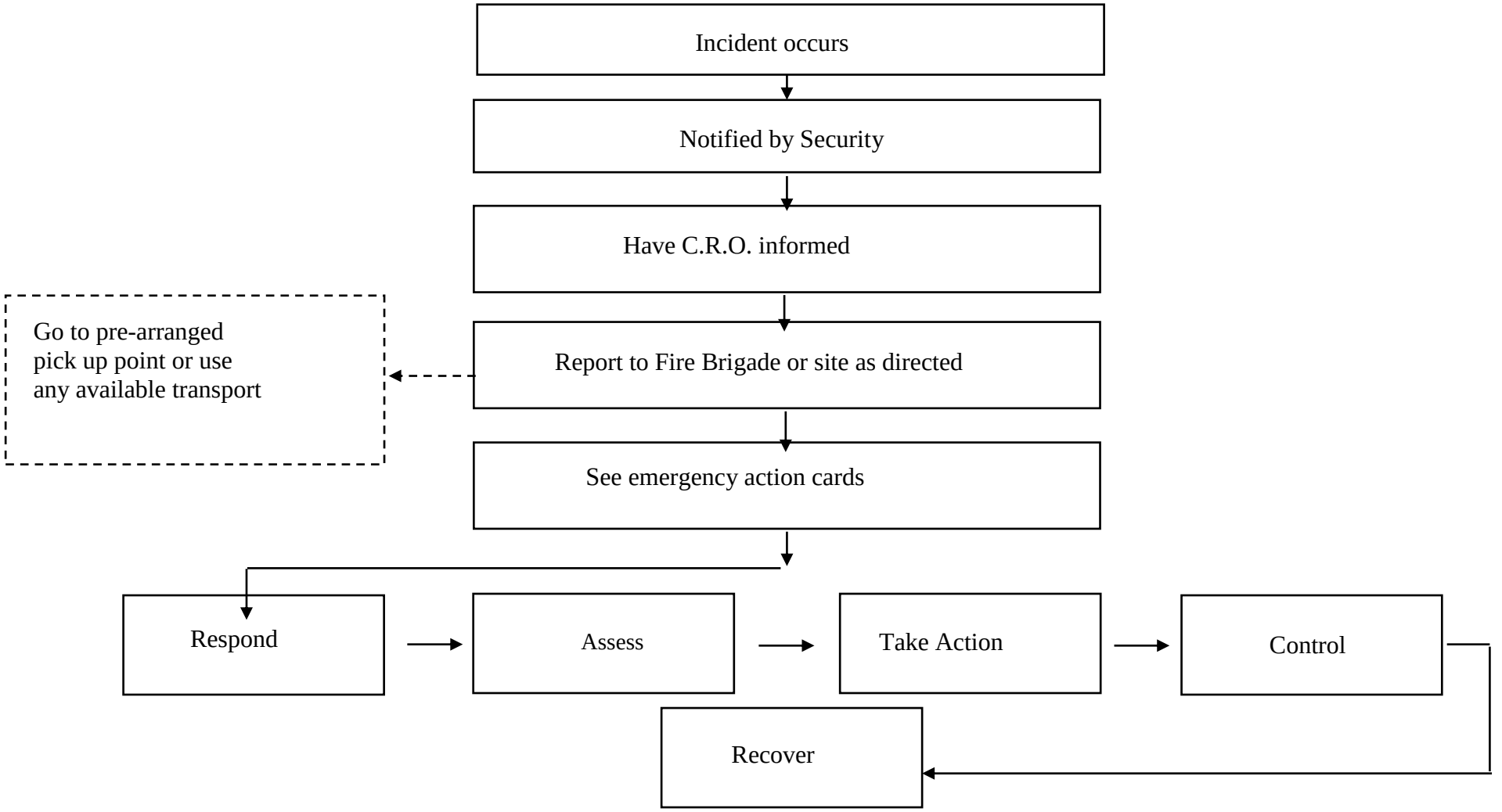


Action Card No. 8



Action Card No. 9

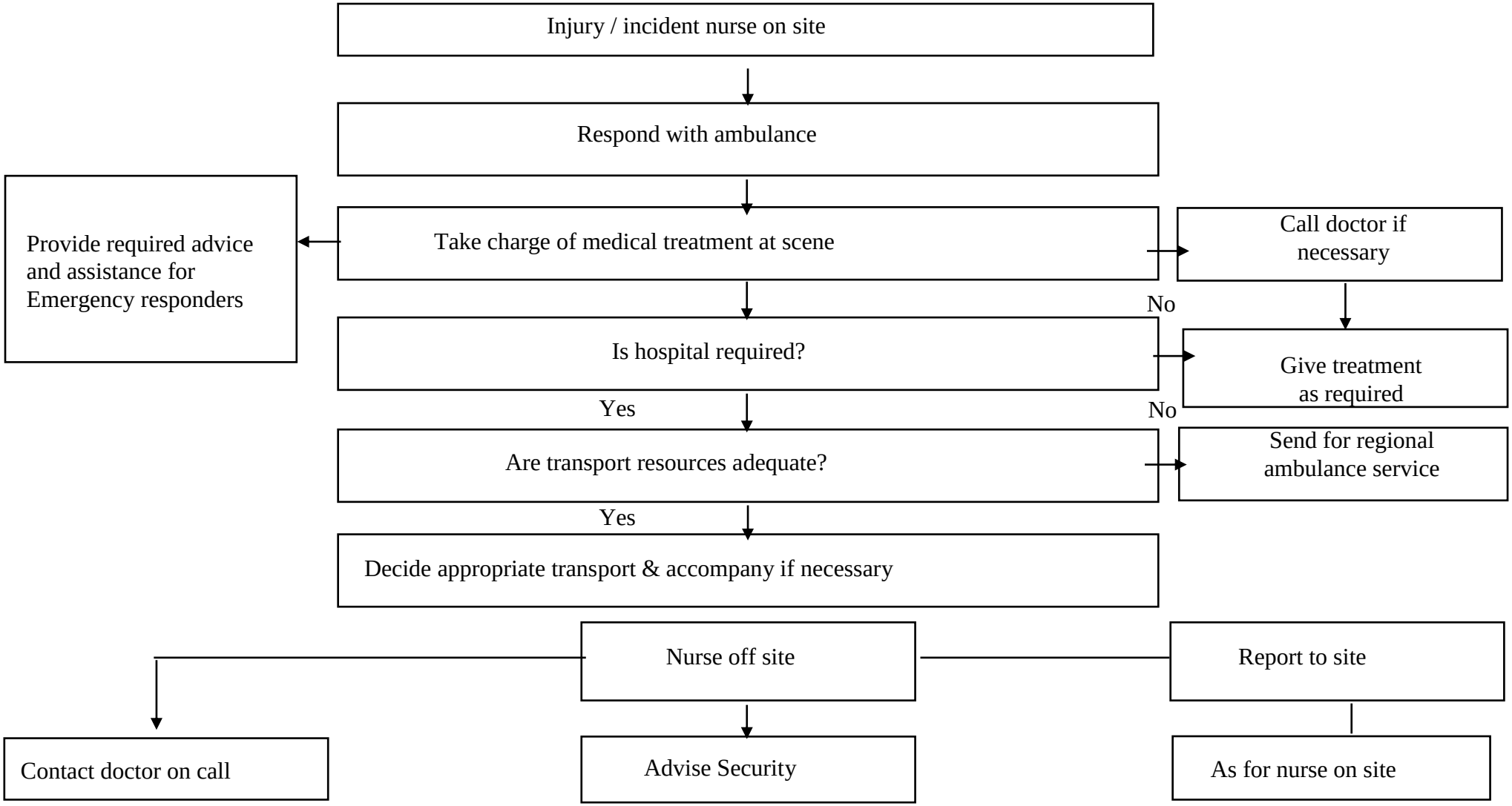
Volunteer Fire Crew Actions



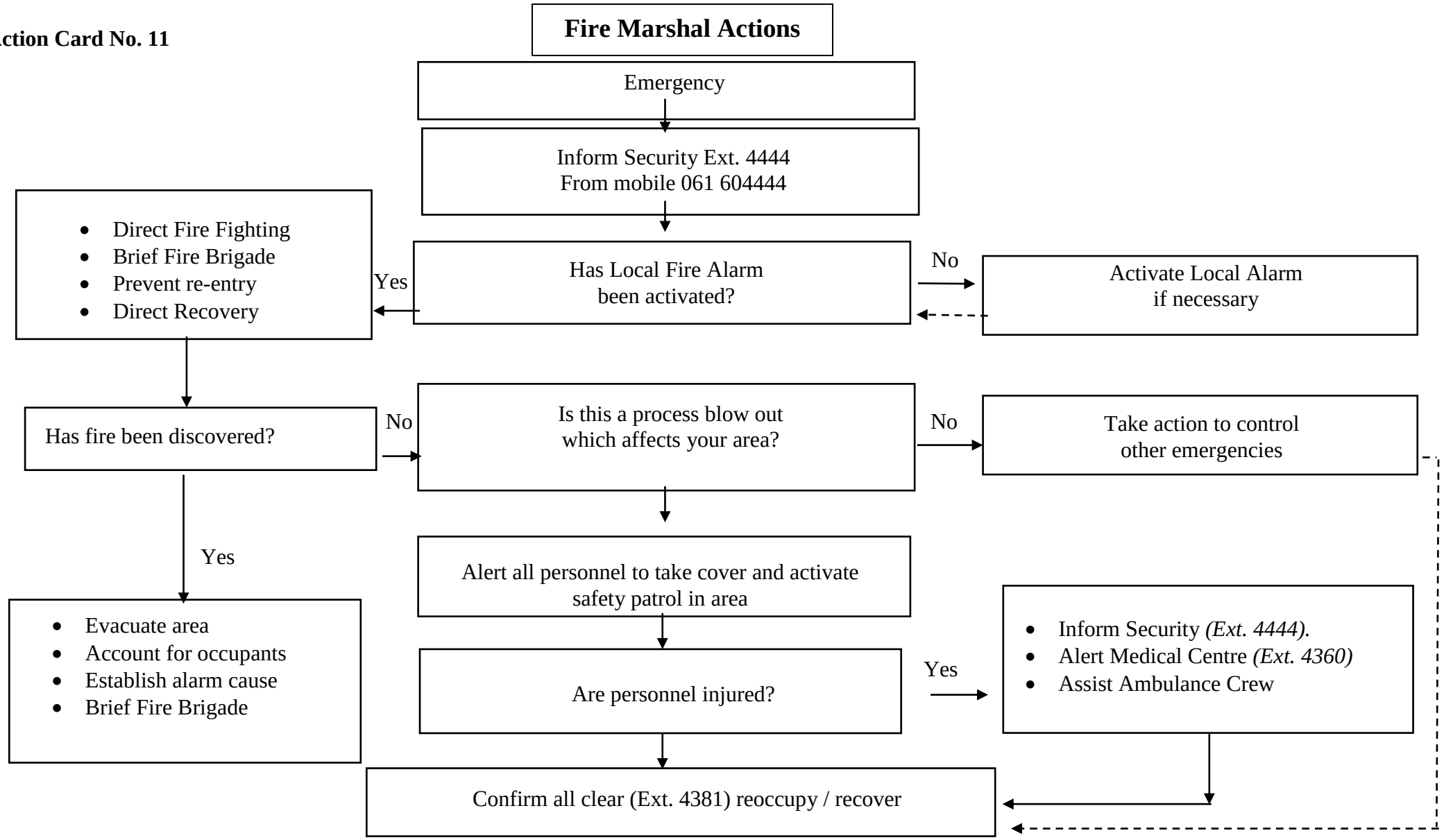
S A F E L Y

Action Card No. 10

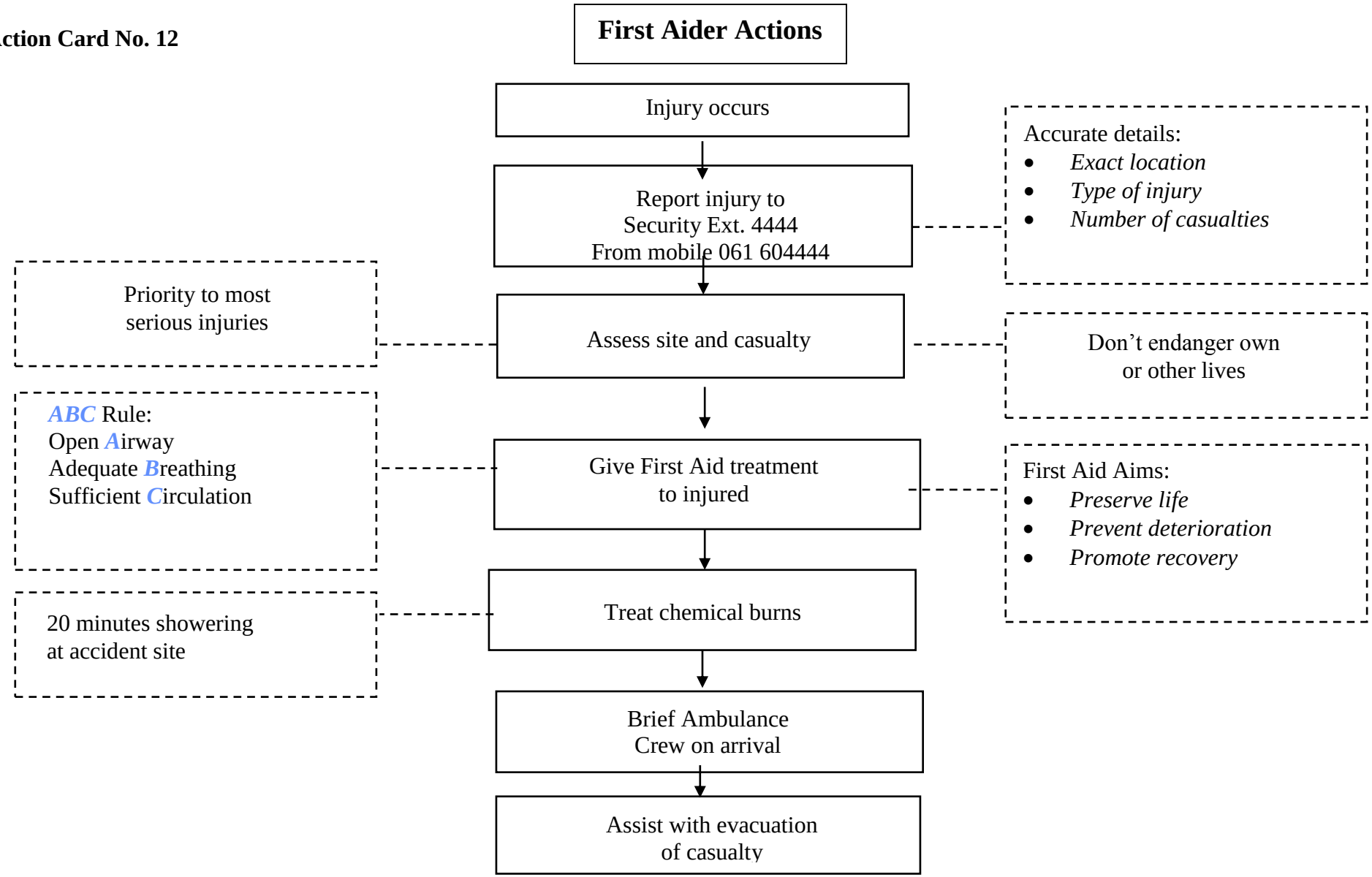
Medical Staff Actions



Action Card No. 11



Action Card No. 12



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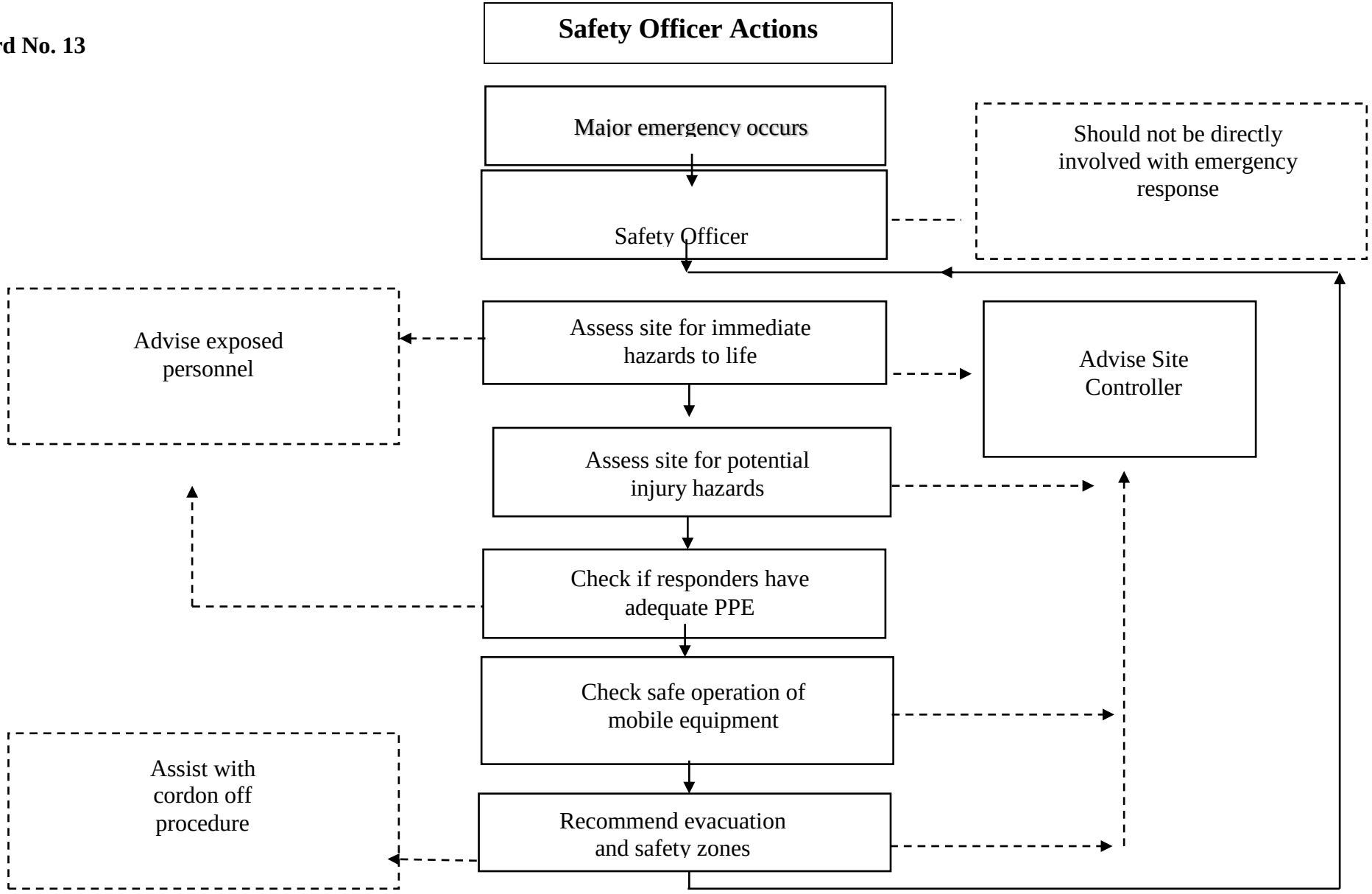


Appendix 2

EXTERNAL EMERGENCY PLAN

BAUXITE RESIDUE DISPOSAL AREA AUGHINISH ALUMINA LTD.

ASKEATON CO. LIMERICK

Title:	**AAL BRDA EXTERNAL EMERGENCY PLAN**
Version:	**1.4**
Date:	**January 2016**
Status:	**FINAL**
Prepared By:	**Limerick City & County Council**

External Emergency Plan – BRDA, Aughinish Alumina Ltd.

This external emergency plan for Bauxite Residue Disposal Area, Aughinish Alumina Ltd., Aughinish West, Askeaton, Co. Limerick has been developed and approved by Limerick City & County Council in accordance with the requirements of the Waste Management (Management of Waste from the Extractive Industries) Regulations, 2009 (S.I. 566 of 2009).

C. Doherty

Limerick City & County Council

Date: Jan 2016

RECORD OF ISSUES AND AMENDMENTS

NOTE: Any changes made to the Aughinish Alumina Ltd. facility with regards to site layout, structure of plant, operating procedures or change/quantity of dangerous substances stored on site, that may have an impact on this External Emergency Plan, shall be notified to the Local Competent Authorities.

External Emergency Plan Working Group (EEPWG)		
Names	**Title**	**Organisation**
Tom Tarpey	Senior Engineer, Environment	Limerick City & County Council
Gerry Doherty	Senior Executive Engineer, Environment	Limerick City & County Council
Niall Murray	Assistant Chief Fire Officer	Limerick City & County Fire and Rescue Service

Documents used in the preparation of this External Emergency Plan	
1	Waste Management (Management of Waste from the Extractive Industries) Regulations, 2009 (S.I. 566 of 2009)
2	EPA Guidance on the Waste Management (Management of Waste from the Extractive Industries) Regulations 2009 – published June 2012
3	A Framework for Major Emergency Management – Guidance Document 10: *Guidance for those Principal Response Agencies that are designated as Local Competent Authorities under S.I. No. 74 of 2006; European Communities (Control of Major Hazards Involving Dangerous Substances) Regulations 2006*
4	*RUSAL Aughinish Emergency Procedures – BRDA Containment Failure – Iss1Rev2 of April 2013*
5	RUSAL Aughinish Emergency Response Plan – March 2013
6	Risk Assessment and Break-Out Study for the Bauxite Residue Disposal Area at Aughinish Alumina – March 2013
7	Aughinish Alumina Ltd. 2005 BRDA Extension Environmental Impact Statement.

Record of Issues and Amendments			
Version No.	**Date**	**Section Amended**	**Amended By**
Issue 1.0	June 2013	Original External Emergency Plan.	Limerick County Council
Issue 1.1	July 2013	Comments from HSE and EPA incorporated	Limerick County Council
Issue 1.2	September 2013	Final version following Public Consultation.	Limerick County Council
Issue 1.3	April 2015	Review following Testing of Plan	Limerick City & County Council
Issue 1.4	January 2016	Final Review following Testing	Limerick City & County Council

Exercise and Review Record		
Date	**Type of Exercise**	**Comments**
06 March 2015	Desk-Top Test of Plan	

TABLE OF CONTENTS

DISTRIBUTION LIST

A copy of the External Emergency Plan has been distributed to the following agencies.

• Limerick City & County Council	Chief Executive
• An Garda Síochána	Chief Superintendent
• Health Service Executive	Regional Emergency Management Office
• Aughinish Alumina Ltd.	Environmental Co-ordinator
• Health and Safety Authority	Manager
• Environmental Protection Agency	Inspector (Cork Office)
• Munster Regional Communications Centre	Senior Executive Emergency Communications Officer
• Shannon Foynes Port Authority	Harbour Master
• National Parks and Wildlife Service (NPWS)	Regional Manager
• Office of Public Works (OPW)	Assistant Chief Engineer, Templemungret

Individual agencies should print sufficient copies for distribution to the relevant personnel within their organisation. As required, the Local Competent Authorities will update the plan and redistribute to the above list.

INTRODUCTION

This is the External Emergency Plan for:-

BAUXITE RESIDUE DISPOSAL AREA (BRDA)
AUGHINISH ALUMINA LTD.
AUGHINISH WEST
ASKEATON,
CO. LIMERICK.

Aughinish Alumina Ltd. is an alumina refinery situated on Aughinish Island on the south side of the Shannon estuary near Foynes, 20 miles downstream from Limerick City.
The plant produces over 1.8 million tonnes of alumina (Al_2O_3) per annum by processing bauxite ore, a reddish brown earth, using the Bayer process. Alumina is a fine white granular powder which is exported to aluminium smelters for processing into aluminium metal.

The Bayer Method results in the production of bauxite residues (primarily non-hazardous but with a 1.0 -1.5% hazardous constituent) which is deposited in the lined Bauxite Residue Disposal Area within the facility boundary. The process yields approximately 0.3 tonnes of waste for disposal for each tonne of bauxite processed. The BRDA comprises 2 separate phases. Phase 1 comprises 104 ha and is substantially filled. Phase 2 comprises 78 ha and is currently being filled. It is estimated that there is 18 years of capacity within the constructed BRDA (to 2031).

The EPA have classified the Bauxite Residue Disposal Area at Aughinish Alumina Ltd. as a Category A Waste Facility as defined in Waste Management (Management of Waste from the Extractive Industries) Regulations, 2009 (S.I. 566 of 2009).

Golder Associates prepared a Risk Assessment and Break-out study of the BRDA in 2012, on behalf of Aughinish Alumina Ltd. This assessment concluded that the probability of a breach or failure of BRDA containment is very unlikely to negligible. Aughinish Alumina Ltd. Emergency Response Procedure considers 2 worst-case scenarios in which a breach or failure of BRDA containment may occur:

1) A release of alkaline waste water in the Perimeter Interceptor Channel over the top of the Outer Perimeter Embankment Wall of the Phase 1 BRDA
2) A release of red mud slurry into the Perimeter Interceptor Channel and over the top of the Outer Perimeter Embankment Wall of the Phase 1 BRDA

This External Emergency Plan has been prepared, in accordance with the requirements of the Waste Management (Management of Waste from the Extractive Industries) Regulations, 2009 (S.I. 566 of 2009).

The relevant Authorities in respect of this External Emergency Plan are:

- Environmental Protection Agency (in respect of IPPC Licencing & Competent Authority under SI 566 of 2009)
- Limerick City & County Council (responsible for preparation of External Emergency Plan as outlined in SI 566 of 2009 and Principal Response Agency)
- An Garda Síochána (Limerick Division) (Principal Response Agency)
- Health Service Executive (West) (Principal Response Agency)

The objectives of this External Emergency Plan are to prepare for:

- Containment and control of major accidents and other incidents so as to minimise their effects and in particular to limit damage to human health and the environment;
- Implementation of measures necessary to protect human health and the environment from the effects of major accidents and other incidents;
- Communication of the necessary information to the public and to the relevant services or authorities in the area;
- Provision for the rehabilitation, restoration and clean-up of the environment following a major accident.

This External Emergency Plan may also be read and implemented in conjunction with:-

- RUSAL Aughinish Emergency Response Plan
- RUSAL Aughinish Emergency Procedures – BRDA Containment Failure
- The Major Emergency Plans of:
  - Limerick City & County Council
  - An Garda Síochána (Limerick)
  - Health Service Executive (West)

In addition to other sources of information, responding organisations / agencies should refer to this External Emergency Plan when responding to a major incident at BRDA Facility, Aughinish Alumina Ltd.

NOTE:

This External Emergency Plan is a specific Sub-Plan of the Major Emergency Plan of each Principal Response Agency. The activation of this External Emergency Plan may not warrant a declaration of a Major Emergency and the activation of the procedures contained within the Major Emergency Plan. A decision on whether or not the emergency requires the activation of the Major Emergency Plan will reside with authorized officers of the Principal Response Agencies.

A *"Framework for Major Emergency Management"* sets out the co-ordination arrangements and terminology for use in the event of a Major Emergency (e.g. Lead Agency concept, Information Management System, On-Site Coordinator, Controller of Operations and Media Liaison Officers etc.). It is also appropriate that Framework arrangements and terminology are used in emergency situations where a Major Emergency has not been declared. These arrangements have been incorporated into this External Emergency Plan where necessary.

1.0 ACTIVATION AND STAND DOWN

1.1 When will this Plan be activated?

This Plan will be activated without delay when:

- A major accident occurs[1]; or
- An uncontrolled event occurs which could be reasonably expected to lead to a major accident.

A major accident[2] is an occurrence on site in the course of an operation involving the management of extractive waste in any establishment covered by Directive 2006/21/EC , leading to a serious danger to human health and/or the environment, whether immediately or over time, on-site or off-site;

1.2 Responsibility for activating this Plan

The following personnel from **Aughinish Alumina Ltd.** may request the activation of this plan:

Name	Position	Contact Number
Ms. Louise Clune	Environmental Co-ordinator	061-604232/243
Mr. Ciaran Kelleher / Mr. John Horan / Mr. Tom Murray	Plant Manager	061-604000

The following personnel from Limerick City & County Council may initiate activation of this plan:

Name	Position	Contact Number
Mr. Kieran Lehane	Director Of Services, Environment	061-496448
Mr. Tom Tarpey	Senior Engineer, Environment & Water Services	061-496444

[1] The term 'major accident' is used to reflect its usage and definition in the Regulations – Waste Management (Management of Waste from the Extractive Industries) Regulations, 2009 (S.I. 566 of 2009) Note that a 'major accident at a Category A Waste Facility may NOT NECESSARILY be of sufficient impact on the capabilities of the emergency services to require the declaration of a Major Emergency under the Framework. The Site Operator should NOT use the METHANE format.

[2] "major accident" defined in Waste Management (Management of Waste from the Extractive Industries) Regulations, 2009 (S.I. 566 of 2009);

1.3 How this plan will be activated?

An authorised member of Aughinish Alumina Ltd. will make a telephone call to the following:

	Limerick City & County Council
1.	Limerick City & County Council Environment Section: 061 496200
2.	Limerick City & County Council Out of Hours Emergency Number: 061 417833

The following personnel will then be contacted to establish the status of the incident:

	Environment Section
1.	Mr. Kieran Lehane, Director of Services
2.	Mr. Tom Tarpey, Senior Engineer

And will contact the following principal response agencies, as required:

	Agency
1.	Limerick City & County Council Emergency Services via the Munster Regional Communication Centre.
2.	H.S.E., Ambulance Command and Control Centre, Dooradoyle, Limerick.
3.	An Garda Síochána Divisional HQ, Henry Street, Limerick.

1.4 Information to be provided

When making the activation telephone call, Aughinish Alumina Ltd. must provide the following information to Limerick City & County Council:

- Site Name and Address:
  AUGHINISH ALUMINA LTD., Aughinish West, Askeaton, Co. Limerick.
- The fact that the BRDA at Aughinish Alumina Ltd. is a Category A Facility and that the emergency requires the activation of the External Emergency Plan. Note if the emergency is environmental and/or if there is risk to human health.
- Provide details of the incident using the following **ETHANE** format:

MNEMONIC 'ETHANE' MESSAGE TO DELIVER		
E	Exact Location	Specific building or installation on site
T	Type of Incident	Fire, explosion, chemical incident, etc.
H	Hazards	Current and potential
A	Access	From which direction to approach
N	Number of casualties	The type/severity
E	Emergency services	Present and required

NOTE:
If it appears to one or more of the Principal Response Agencies that a major accident has occurred or an uncontrolled evnt has occurred which could be reasonably expected to lead to a major accident at Bauxite Residue Disposal Area, Aughinish Alumina Ltd., then Limerick City & County Council should activate this plan as set out above for BRDA, Aughinish Alumina Ltd.

On activation of this plan the Principal Response Agencies will implement their key actions as outlined in Section 2.

The Principal Response Agencies also have their own Major Emergency Plans, which shall be activated in the event of a major emergency (See Section 1.6).

1.5 Initial Actions of Principal Response Agencies

The Incident Commanders from each of the Principal Response Agencies are to meet the Site Manager at the pre-determined meeting point, which is the reception/security building at Aughinish Alumina Ltd. The Aughinish Alumina Ltd. Plant Management may change the location of the meeting point on activation of this plan.

The designated Controller of Operations from each of the Principal Response Agencies shall meet at the On-Site Co-ordination Centre, which is situated in the Reception/Security building at Aughinish Alumina Ltd.

1.6 Major Emergency

DEFINITION
A Major Emergency is any event which, usually with little or no warning, causes or threatens death or injury, serious disruption of essential services or damage to property, the environment or infrastructure beyond the normal capabilities of the principal emergency services in the area in which the event occurs, and requires the activation of specific additional procedures and the mobilization of additional resources to ensure an effective, co-coordinated response.

Any one of the three Principal Response Agencies (An Garda Síochána, Health Service Executive and Limerick City & County Council) may declare a major emergency, which will activate each agencies pre-determined arrangement in response to a major emergency.

1.7 Standing Down of the Plan

Where a Major Emergency has been declared by one of the Principal Response Agencies, the decision to stand down the incident at the site, and to announce an "All Clear" to the public, will be taken by the On Site Co-ordinator, in consultation with the other Controllers of Operations at the site and the Local Co-ordination Group.

Where a Major Emergency has <u>not</u> been declared, the decision to stand down this External Emergency Plan and to announce an "All Clear" to the public will be taken by the On-Site Coordinator of the lead Principal Response Agency, in consultation with the Controllers of Operations from the other Principal Response Agencies and the Environmental Co-ordinator of Aughinish Alumina Ltd.

2.0 KEY ACTIONS

2.1 Aughinish Alumina Ltd.

KEY ACTIONS – Aughinish Alumina Ltd.	
1.	Implement the pre-determined emergency response arrangements as set out in the Internal Emergency Plan (comprising Rusal Aughinish Emergency Response Plan and BRDA Containment Failure – Emergency Procedure).
2.	Contact Limerick City & County Council to prompt the activation of this External Emergency Plan and provide all relevant information provided as per sections 1.3 and 1.4 of this plan. Contact EPA as per Condition 9.3 of AAL's IPPC Licence.
3.	Ensure that a Meeting Point is identified and communicated to the Principal Response Agencies.
4.	Arrange for the Environmental Co-ordinator to meet with the Senior Officers of the Principal Response Agencies at the agreed Meeting Point.
5.	Provide all relevant information to the Principal Response Agencies in relation to the incident. Provide site specific PPE and diphotherine spray to agencies where required. Identify location of drench showers and additional supplementary supplies of PPE / dipotherine on the BRDA road.
6.	Ensure that there is a co-ordinated public and media response to the emergency as outlined in Section 6.0 of the External Emergency Plan.

2.2 Limerick City & County Council

KEY ACTIONS – LIMERICK CITY & COUNTY COUNCIL	
1.	Consider the requirement to declare a Major Emergency as per the Limerick City & County Council Major Emergency Plan.
2.	Turn out Controller of Operations who will take command of the Local Authority response. Note that the Controllers of Operations for Major Emergencies are nominated in the Major Emergency Plan. Where the incident is not a major emergency, those activating the plan may nominate a Controller of Operations.
3.	Establish own agency liaison with*:- a. Principal Response Agencies b. Office of Public Works (OPW) c. Shannon Foynes Port Authority d. The Environmental Protection Agency (EPA) e. National Parks and Wildlife Service (NPWS) f. LCCC Local Area Staff * (Refer to Section 9 for contact details)
4.	Obtain more detail regarding the incident from Aughinish Alumina Ltd., such as:- A. Establish initial contact with the Aughinish Alumina Ltd. Environmental Co-ordinator at the designated Meeting Point. B. Identify Rendezvous Point (RVP) to be used and communicate to the other Principal Response Agencies. The primary RVP for Aughinish Alumina Ltd. will be the carpark to the Reception/Security building (Area 79) which is located to the North East of the BRDA. These locations are highlighted in Appendix B of this plan.
5.	Establish Inter –Agency Media and decide on appropriate response. All Media Statements to be approved by the On-site Co-ordinator.
6.	Review potential contamination pathways and receptors and Aughinish Alumina Ltd. response. Provide additional resources to facilitate the response as required. There is no direct public access to the river along the AAL boundary of the BRDA. However, the public paths on the adjacent side of the river should be managed and secured to prevent pedestrian access to the river. Residents local to the Robertstown River should also be advised of the situation as per Section 6 of this plan. This may also include ambulance where there is risk to personnel, fire tender where pumping arrangements may be required and machinery/materials to strengthen and maintain earth barriers to limit contamination pathways. Provide relevant information to responding units as it becomes available.

7.	Carry out a dynamic risk assessment for the incident with the Environmental Co-ordinator from Aughinish Alumina Ltd. or deputy and determine what resources are required in the first instance to deal with the incident. This may include monitoring of watercourses adjacent to the BRDA to establish the extent of the impact of the incident. (This may require support from SEA-PT and LCCC Laboratory)
8.	Establish a Danger Area. (Consider the Specified Area as shown in Appendix C).
9.	Establish an Operational Plan.
10.	Operate the Incident Command System for dealing with the incident.
11.	Identify additional resource requirements.
12.	Provide a marshalling officer at Rendezvous Point (RVP) if resources allow.
13.	Ensure additional resources arrive at RVP and are directed to site or Holding Area as required.
14.	Consult with the other responding agencies and Aughinish Alumina Ltd. about what action should be taken to communicate the conclusion of the incident and the "all clear" to the public.

2.3 An Garda Síochána

KEY ACTIONS – AN GARDA SÍOCHÁNA	
1.	Consider the requirement to declare a Major Emergency as per An Garda Síochána Major Emergency Plan for the division.
2.	Establish the requirement to have a Garda Siochána officer-in-charge at the site.
3.	Establish clear and robust communications with An Garda Síochána officer-in-charge at the site.
4.	Establish communications with other responding agencies. (Include Media Liaison Officer contact with other agencies)
5.	Activate a Traffic Management Plan (where required).
6.	Pass to the Garda Press Office any necessary warning to the public, in accordance with the Limerick City & County Inter-Agency Media Plan and Section 6.0 of this External Emergency Plan.
7.	Depending on information received as to risk scenario, identify safe approach route to the primary Rendezvous Point. Once established, deploy an officer there to liaise with the lead agency Controller of Operations.
8.	Appoint a Garda Controller of Operations who will take command of Garda resources in managing any off site consequences.
9.	Identify locations for Garda Incident Command Vehicle.
10.	Ensure that sufficient Garda resources are deployed to the incident jointly with Aughinish Alumina Ltd. and other responding agencies.
11.	Consider what action should be taken to communicate the conclusion of the incident and the "All Clear" to the public.
13.	Manage personnel when they arrive at the assembly points.

2.4 Health Service Executive – (West)

KEY ACTIONS – HEALTH SERVICE EXECUTIVE -WEST	
1.	Consider the need to declare a Major Emergency as per the Health Service Executive (West) Major Emergency Plan.
2.	Mobilise and dispatch the pre-determined attendance (PDA).
3.	Obtain more detailed information regarding the incident from the Operator, or the other Principal Response Agencies, as appropriate.
4.	Provide relevant information to responding units, as it becomes available.
5.	Provide all responding staff with information pertaining to Health & Safety, danger area and need for personal protective equipment.
6.	Respond to designated RVP using pre-determined designated routes.
7.	Alert Mid Western Regional Hospital, Dooradoyle.
8.	Alert adjoining Ambulance Control Centres.
9.	Consider the mobilisation of the Decontamination Unit
11.	Determine availability of on-site facilities for:- • Casualty Management • Decontamination

2.5 Health Service Executive – (West) On-Site

KEY ACTIONS – HEALTH SERVICE EXECUTIVE –WEST (ON-SITE)	
The Ambulance Service will execute Ambulance Service Standing Orders for the site of a Major Emergency. In particular, the senior HSE Ambulance Officer at the site should:-	
1.	Report to Ambulance Control using ETHANE.
2.	Act as HSE Controller of Operations, if required.
3.	Meet Controllers of Operations of other two Principal Response Agencies at the predetermined On-site Co-ordination Centre.
4.	In consultation with the other Controller of Operators, agree locations for Incident Control, Casualty Clearing Station, Ambulance Loading Point, Body Holding Area and HSE Holding Area, as appropriate.
5.	Prepare a report from the site for the Area Crisis Management Team, using the normal reporting structure, and provide further updates, if appropriate.
6.	Request the activation of additional HSE services through the Ambulance Management Team to the HSE Area Crisis Management Team, if appropriate.
7.	Liaise with other HSE services if required.
8.	Consider the mobilisation of the Decontamination Unit.
9.	Update Ambulance Control, on a regular basis, with information on the status of the incident, numbers and types of casualties, dispatch of casualties to hospitals, etc.

3.0 ON-SITE INFORMATION

3.1 Details of Materials present at BRDA, Aughinish Alumina Ltd.

This plan has been prepared to respond to major incidents involving materials that are present at BRDA, Aughinish Alumina Ltd. The materials concerned are as follows:

<table>
<tr><th>Substance</th><th>Comments / Data relevant to Relevant Materials</th></tr>
<tr><td>Red Mud Slurry</td><td>This is the principal by-product of the alumina extraction process. It is a red mud, a reddish brown bauxite residue which remains after the extraction process and which derives its colour from the iron oxide content. It is characterised by an alkaline pH (~11) due to the presence of residual caustic soda from the alumina extraction process. The mud is classified as a non-hazardous waste (EWC 01 03 09) and its typical analysis is:
<table>
<tr><th>Dry Basis</th><th>Red Mud %</th></tr>
<tr><td>Iron oxide (Fe2O3)</td><td>45</td></tr>
<tr><td>Alumina (Al2O3)</td><td>20</td></tr>
<tr><td>Silicon dioxide (SiO2)</td><td>11</td></tr>
<tr><td>Titanium dioxide (TiO2)</td><td>10</td></tr>
<tr><td>Calcium oxide (CaO)</td><td>7</td></tr>
<tr><td>Sodium oxide (Na2O)</td><td>6</td></tr>
<tr><td>P2O5</td><td>0.4</td></tr>
<tr><td>Cr2O3</td><td>0.3</td></tr>
<tr><td>MgO</td><td>0.1</td></tr>
<tr><td>MnO</td><td>0.05</td></tr>
</table></td></tr>
<tr><td>Alkaline Water</td><td>Run-off from the surface of the BRDA is also alkaline due to its contact with the mud, this collects into the perimeter channel and also has a pH of <11.5. During storms with heavy rainfall, the pH will be reduced and closer to pH 11.</td></tr>
</table>

Table 3.1: Summary of Materials at BRDA

3.3.1 Human Health

Both the red mud slurry and associated run-off water are alkaline in nature (mud with a pH of 10.5-11 and water with a pH of <11.5). Direct contact with either of these substances can result in skin and eye irritation and possible worsening of any pre-existing skin disorders. This may be from direct contact of from splashes while working adjacent to the alkaline water channels.

3.3.2 Environmental Impact

Alkaline water release into the Estuary or Robertstown Creek could have an effect on aquatic life. The communities most likely to be impacted would be sessile sublittoral and littoral communities and benthic communities. This would include barnacles, mussels, oysters and shore crabs. Larger mobile species such as dolphins, salmon, otters and shore birds can easily move on to other areas away from the effects of any pollutant.

It is expected that the impact of any alkaline water release would be minimal due to the assimilative capacity of the large watercourse and the tidal influence. Laboratory testing indicates that at a ratio of 1:1 water with pH of <11.5 (such as that contained in perimeter channels) and water with pH of 8.2 (Estuary Water) neutralise to a pH of 10. At a ratio of 25:1 the resulting pH would be 9.
Sampling of the waters would be undertaken to determine any increase in alkalinity and sampling would be continued until such time as the baseline alkalinity is re-established. Landowners adjacent to the potential affected areas (shown in Appendix F) would be notified of any risk.

The release of red mud or alkaline water could also introduce increased suspended solids to the watercourses. This could result in increased siltation and a greater risk of smothering of organisms and habitats.

3.4 Possible Major Accident Scenarios for Aughinish Alumina Ltd.

The major accident scenarios which are considered for this facility are tabulated below and are discussed in more detail in Appendix E of this External Emergency Plan.

It is noted that there are regular inspections throughout the day/night of the BRDA by AAL staff and it is expected that any breach / failure would be identified soon after occurring.

It is also noted that the outfall from the lowlands of the BRDA is via a penstock control and tidal flap valve.

Scenario	Description
1.	Release of alkaline waste water in the Perimeter Interceptor Channel over the top of the Outer Perimeter Embankment Wall of the Phase 1 BRDA.
2.	Release of red mud slurry into the Perimeter Interceptor Channel and over the top of the Outer Perimeter Embankment Wall of the Phase 1 BRDA.

Table 3.4: Summary of Major Accident Scenarios for Aughinish Alumina Ltd.

4.0 INFORMATION FOR PRINCIPAL RESPONSE AGENCIES

4.1 The Specified Area

The Specified Area is the area which is liable to be affected by a major accident at the establishment. This area has been determined by Golder Associates in preparing the Risk Assessment and Break-out study of the BRDA.

The impact of a discharge via a sluice outlet known as "OPW Sluice" to the Robertstown Creek has also been considered. The impact of this discharge is dependent on the flow rate via the sluice and while it is anticipated that the assimilative capacity of the river will ensure there is minimal risk, which would be confirmed by on-site testing, by way of precaution, those living within a 100m distance from the high water table should be alerted in the event of any such discharge.

The Specified Area for BRDA, Aughinish Alumina Ltd.is outlined in Appendix C of this plan.

Appendix F details those landowners located within the Specified Area or deemed to be sufficiently close to warrant notification in the event of an incident.

4.2 The External Emergency Planning Zone

The Major Accident Scenarios are outlined in Section 3.4 of this plan. The landowners to be notified are detailed in Appendix F. Once the exact extent of the incident is established the Controller of Operations may decide to amend the zones and to facilitate the movement of traffic and local community.

4.3 Details of Site Access and Egress Routes

4.3.1 Primary Access

The primary access and egress route to the BRDA at Aughinish Alumina Ltd.is from the N69 from the Askeaton side (East) and into the main entrance of Aughinish Alumina Ltd. This is shown in Appendix B of this plan.

4.3.2 Alternative Access

The alternative access and egress route to the Aughinish Alumina Ltd. facility is from the N69 from the Foynes side (West) into the main entrance. This is shown in Appendix B of this plan.

4.4 Location of Aughinish Alumina Ltd. Incident Command Point

The primary location for the Incident Command Point will be the Reception/Security Building at Aughinish Alumina Ltd. (Area 79). This is highlighted in Appendix B of this plan.

If this area is threatened, the Incident Command Point maybe located in an area agreed by the Controller of Operations from each of the Principal Response Agencies. The Principal Response Agencies Incident Command Vehicles can be used as an alternative.

4.5 Location of the Primary Rendezvous Point

The primary Rendezvous Point (RVP) is situated at the carpark adjacent to the Reception/Security building (Area 79). This location is outlined on the site layout plan shown in Appendix B of this plan.

4.6 Location of the Primary Holding Area

The location of the Principal Response Agency Holding Area has been identified as the carpark adjacent to the Reception/Security Building (Area 79). An alternative to this Holding Area can be agreed by the Controller of Operations from each of the Principal Response Agencies, where necessary. The Holding Area is highlighted in the site location map in Appendix B of this plan.

4.7 Location of the On-Site Co-ordination Centre

On declaration of a Major Emergency, the location of the On-site Co-ordination Centre (OSCC) has been identified as:

- **Conference Room: Reception / Security Building (Area 79) at Aughinish Alumina Ltd.**

This is identified in Appendix B of this plan. The Incident Command Vehicles of the Principal Response Agencies will advance to the designated RVP and await direction from the Incident Commander.

4.8 Adjacent Buildings

There are a total of 13 private dwellings within 100m of the Robertstown Creek and these are shown in Appendix F.

4.9 Details of Environmentally Sensitive Areas

The Specified Area associated with the BRDA includes the Lower River Shannon Special Area of Conservation (SAC). In addition the Specified Area includes the River Shannon and Fergus Estuaries Special Protection Area (SPA) and the proposed National Heritage Area (pNHA) of Inner Shannon Estuary – South Shore

Details about these environmentally sensitive areas are described in Appendix E.

4.10 Details of Land Use

The use of land surrounding BRDA - Aughinish Alumina Ltd. is identified as landscaped buffer area with the Limerick City & County Council Shannon Estuary Water Treatment Works to the South East of the BRDA.

4.13 Hazards to People in the Area

There are a number of residential dwellings within a 100m distance from the High Water Level of Robertstown River. People may be at risk if they come in contact with waters with high pH as per Section 3.3.1 of this External Emergency Plan.

4.14 Specific Hazards to the Environment

See 3.3.2

5.0 INFORMATION AVAILABLE TO THE PUBLIC

5.1 Information provided to the public prior to an Incident Occurring

Any persons occupying the specified area will be informed by Aughinish Alumina Ltd. in the event of an actual or threatened major emergency.

The defined specified area is entirely in the ownership of Aughinish Alumina Ltd. and therefore the occupants will primarily consist of Aughinish Alumina Ltd. staff and/or any other occupants of the lands.

Separately, Limerick City & County Council have defined an Area which is adjacent to the Specified Area and any residents within this area will be provided with information advising of the procedures to be taken in the event of an actual or threatened major emergency.

The information issued beforehand advises the public to:

- Avoid contact with watercourses in the area.
- Listen to the local radio for information updates
- Follow any instructions from the Principal Response Agencies (HSE, Gardai, Limerick City & County Council)

Further guidance is included to ensure that affected households and individuals will listen to information broadcasts by the Principal Response Agencies on public radio as the emergency progresses.

5.2 When the Information will be issued

An information leaflet containing all the relevant information has been provided to those residents located with a 100m distance from the High Water Level of Robertstown River An updated version of this leaflet will re-issue should there be any significant change to the information provided within the leaflet.

5.3 Method of Providing Information to the public

The relevant information will be provided to the public using the following means:

- An information leaflet, produced by Limerick City & County Council, distributed to households in the area.

6.0 WARNING AND INFORMING THE PUBLIC DURING AN INCIDENT

6.1 How the Public will be notified of an Incident

Following the determination of the extent of the incident, Limerick City & County Council will inform the public of an incident by directly contacting people residing within the 100m high water level. (Appendix F).

6.2 How the Public will be kept Informed during an Incident

Information regarding the emergency will be communicated using media such as house-to-house visits, direct telephone and / or local radio.

Procedures will be put in place by the responding agencies to keep the public informed during and after an incident. This is outlined in Section 8.

6.3 How the Public will be notified of the 'ALL CLEAR'

Where a Major Emergency has been declared, the decision to announce an 'All Clear' to the public will be taken by the On Site Co-ordinator, in consultation with the other Controllers of Operations at the site and with the Local Co-ordination Group.

Where a Major Emergency has not been declared, the decision to announce an 'All Clear' to the public will be taken by the Controller of Operations of the lead responding agency and the Site Operator, in consultation with the Controllers of the other responding organisations.

The methods chosen to notify the 'All Clear' for Aughinish Alumina Ltd. will depend on the nature and extent of the incident and its impact on the public.

Notwithstanding that the site has been declared clear, the Controllers of Operations together with the Principal Response Agencies Media Liaison Officers (and as / where appropriate a media representative from Aughinish Alumina Ltd.) should consider the effect of the incident on the public and prepare and issue advice on any measures necessary for members of the public to manage the aftermath of the incident and the return to normality.

7.0 WORKING WITH THE MEDIA

7.1 Inter-Agency Media Plan

Each Principal Response Agency shall alert their Media Liaison Officers on activation of the External Emergency Plan.

The Media Liaison Officers shall initiate a teleconference as per the Inter-Agency Media Plan to decide on the appropriate response.

The activities of the Media Liaison Officers at the site will be co-ordinated by the Media Liaison Officer of the Lead Agency. All statements to the Media should be approved by the On-Site Co-ordinator.

The Media Briefing Centre for a major emergency in Limerick County will be one of the pre-determined locations outlined in the Limerick City & County Council's Media Communications Sub Plan.

7.2 Co-ordination with Aughinish Alumina Ltd. Media Strategy

In conjunction with Aughinish Alumina Ltd. Media Response Arrangements outlined in Sections 2.8, 2.9 and Action Card No. 8 of the RUSAL Aughinish Emergency Response Plan. The media liaison contact provided by Aughinish Alumina Ltd. should liaise with the Media Liaison Officers of the Principal Response Agencies to ensure a co-ordinated response to the media.

8.0 RECOVERY

8.1 Recovery Stage of an incident

Where a major emergency has been declared, the management of the recovery from the effects of the emergency will conform in general with Section 6 of the Major Emergency Plans for Limerick City & County Council, An Garda Síochána and Health Service Executive.

It is possible that the Lead Agency will change over the incident, especially during the recovery stage. All changes in the ownership of the Lead Agency role should be reviewed at appropriate stages of the incident by the three Controllers of Operations. The Lead Agency designation emanating from the site, and the timing thereof, should be recorded and communicated as per initial determination.

8.1 Clean-up Operations

RUSAL Aughinish BRDA Containment Failure Emergency Procedure details suitable and sufficient provisions for the restoration and clean up of the environment within the site ownership following a major accident.

Environmental Clean-Up operations required where there is a discharge to the Estuary and/or Robertstown River will be determined following testing of the waters to confirm contamination.

8.2 Organisations to be consulted

Contact Details		
Name	**Address**	**Contact Number**
Environmental Protection Agency	P.O. Box 3000, Johnstown Castle Estate, Wexford	Ph: 053-9160600 Fax: 053-9160699 Emergency Pager Number: 0890 335599
HSE (Public Health)	Public Health Dept., Catherine Street, Limerick	061-483439
National Parks & Wildlife Service (NPWS)	7 Ely Place, Dublin 2.	(01) 8883242

8.3 Arrangements that the Site Operator has to support the Community following an Incident

To support the Community following the incident, Aughinish Alumina Ltd. will ensure that they have all relevant insurances in place.

8.4 Arrangements that An Garda Síochána will put in place to support the Community following an Incident

An Garda Síochána shall provide all necessary and appropriate information on the investigations, as soon as it is possible.

Otherwise, An Gárda Síochána will comply with the provisions of the Major Emergency Plan, as applicable in the circumstances during the recovery phase.

8.5 Arrangements that Health Service Executive will put in place to support the Community following an Incident

The HSE shall assess the health needs of the community and consider the scale of immediate and ongoing needs for assistance in the circumstances of the emergency. The following needs in particular will be considered:

- The health needs of any persons affected by the emergency.
- Provide a point of contact for the provision of information and for dealing with the health concerns of the community.
- Provide advice on environmental health in the circumstances of the emergency

8.6 Arrangements that Limerick City & County Council will put in place to support the Community following an Incident

Limerick City & County Council shall make arrangements to provide appropriate support, assistance and advice to people affected by the emergency.

Limerick City & County Council shall establish a list, in priority order, of remedial works / actions, with a view to dealing with such works / actions in a speedy and efficient manner.

Limerick City & County Council shall at the earliest possible time, establish any remedial works / actions, which are outside its own control / function, and shall determine the speediest means of their alleviation, including legal remedy, if necessary.

Limerick City & County Council Environmental Section will advise on testing requirements, carrying out the clean-up and restoration in the event of a major environmental emergency.

Limerick City & County Council will prepare a post-incident evaluation and a resulting Incident Report for circulation to all other agencies.

9.0 CONTACT DIRECTORY

NOTE: A more comprehensive contact list is provided in each of the Principal Response Agency's Major Emergency Plan.

Aughinish Alumina Ltd.		
Name	**Position**	**Contact Number**
Aughinish Alumina Ltd.		Phone: 061 604000 Fax: 061 604090
Louise Clune	Environmental Co-ordinator	Mobile: 087 2949763
Rob McLean	Safety & Security Co-ordinator	Mobile: 0872845963
Nelius Kennedy	Public Affairs Co-ordinator	Mobile: 0872806920
Please refer to Section 8 of RUSAL Aughinish BRDA Containment Failure Emergency Procedure for more contact details.		

Principal Response Agencies		
Limerick City & County Council	County Hall, Dooradoyle	Office Hours: 061-496000 Out of Office Hours: 061-417833
An Garda Síochána	Henry Street Garda Station	061-212400
Health Service Executive	Regional Emergency Management Office	091-775080/775079

National Parks & Wildlife Service	
Eamonn Meskill – Regional Manager	064 6631440

Environmental Protection Agency	
Environmental Protection Agency (Wexford)	053-9160600
Environmental Protection Agency (Cork – OEE Inspector)	021 4875540
Emergency Pager Number	1890 355 599

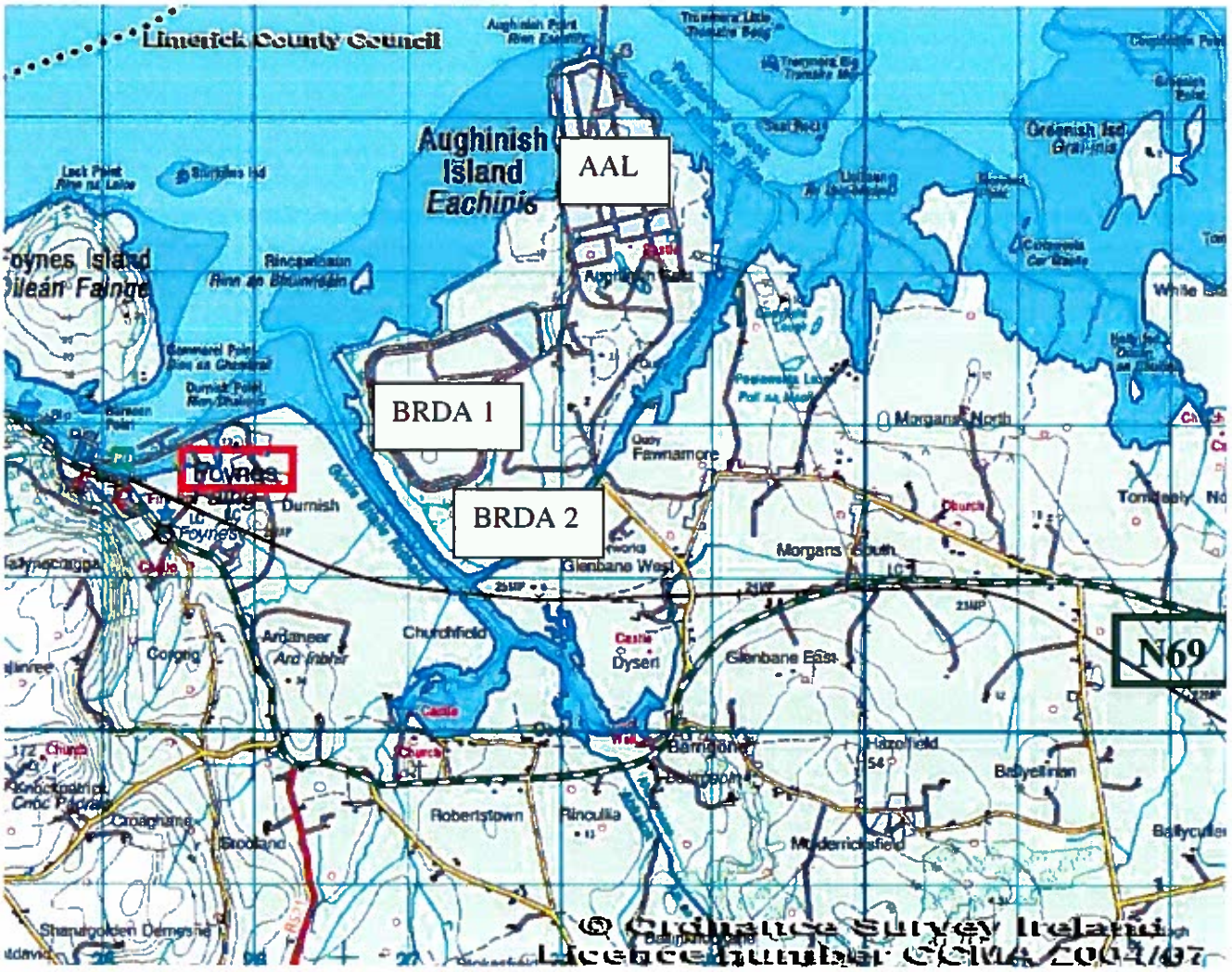
Health Service Executive	
Ambulance Service	999/112
Mid Western Regional Hospital, Dooradoyle, Co. Limerick	Ph: 061-301111 Fax: 061-301165
Regional Emergency Management Office	091-775080/775079

Medical Assistance	
Dr. Susanne Fitzgibbon – Askeaton	061-392267
Dr. Eileen Cassidy – Foynes	069-65196
Dr. Liam Lynch – Rathkeale	069-64464
Dr. T. K. Curtin – Rathkeale	069-64304
Shannon Doc	1850212999

10.0 SCHEDULE OF APPENDICES

Appendix	Title
A	Site Location Map
B	Site Layout Map
C	Specified Area
D	Environmentally Sensitive Areas
E	Summary of Risk Assessment and Break-Out Study by AAL
F	Residential Properties to be Informed Prior to and during an Incident
G	Definitions

APPENDIX A -SITE LOCATION MAP



APPENDIX G -DEFINITIONS

Definitions are taken from A Framework for Major Emergency Management – Guidance Document 10: *Guidance for those Principal Response Agencies that are designated as Local Competent Authorities under S.I. No. 74 of 2006; European Communities (Control of Major Hazards Involving Dangerous Substances) Regulations 2006* except where amended as shown*

Controller of Operations	The person given authority by a principal response agency to control all elements of its activities at and about the site.
Cordons	The designated perimeters of an emergency site, with an Outer Cordon, an Inner Cordon, a Traffic Cordon and a Danger Area Cordon, as appropriate.
Crisis Management Team	A tactical level management group, which consists of senior managers from within the principal response agency, which is assembled to manage a crisis and deal with issues arising for the agency both during the emergency and the subsequent recovery phase.
Danger Area	Areas where there is a definite risk to rescue personnel, over and above that which would normally pertain at emergency operations.
Decontamination	A procedure employed to remove hazardous materials from people and equipment.
Evacuation	The process whereby people are directed away from an area where there is danger, whether immediate or anticipated.
Evacuation Assembly Point	A building or area to which evacuees are directed for onward transportation.

Holding Area	An area at the site, to which resources and personnel, which are not immediately required, are directed to await deployment.
Information Management Officer	A designated member of the support team of a Principal Response Agency who has competency/training in the area of information management.
Information Management System	The Information Management System is to assemble available data and to present decision makers with relevant information as a sound basis for their decision making function. The Information Management System is structured into four fields, which consist of Recognised Current Situation, Key Issues, Strategic Aim/Priorities and Actions.
Lead Agency	The Principal Response Agency that is assigned the responsibility and mandate for the coordination function in response to a major emergency.
Local Co-ordination Centre	A pre-nominated building, typically at county or subcounty level, with support arrangements in place, and used for meetings of the Local Co-ordination Group.
Local Co-ordination Group	A group of senior representatives from the three Principal Response Agencies (An Garda Síochána, HSE and Local Authority) whose function is to facilitate strategic level co-ordination, make policy decisions, liaise with regional/national level coordination centres, if appropriate, and facilitate the distribution of information to the media and the public.

Major Emergency Plan	A plan prepared by each of the Principal Response Agencies in responding to a major emergency.
Major Emergency	Any event which, usually with little or no warning, causes or threatens death or injury, serious disruption of essential services, or damage to property, the environment or infrastructure beyond the normal capabilities of the principal emergency services in the area in which the event occurs, and requiring the activation of specific additional procedures to ensure effective, co-ordinated response.
Major Accident*	A major accident is an occurrence on site in the course of an operation involving the management of extractive waste in any establishment covered by Directive 2006/21/EC 1 , leading to a serious danger to human health and/or the environment, whether immediately or over time, on-site or off-site;
Meeting Point	An agreed location for the initial meeting of the Principal Response Agencies with the site operator.
On-Site Coordinator	The person from the lead agency with the role of coordinating the activities of all agencies responding to an emergency.
On-Site Coordination Centre	Specific area/facility at the Site Control Point where the On-Site Co-ordinator is located and the On-Site Coordination Group meet.
On-Site Co-ordination Group	Group that includes the On-Site Co-ordinator and the Controllers of Operations of the other two agencies, an Information Management Officer, a Media Liaison Officer and others as appropriate.

Principal Emergency Services (PES)	The services which respond to normal emergencies in Ireland, namely An Garda Síochána, the Ambulance Service and the Fire Service.
Principal Response Agencies (PRA)	The agencies designated by the Government to respond to Major Emergencies i.e. An Garda Síochána, the Health Service Executive and the Local Authorities.
Regional Co-ordination Centre	A pre-nominated building, typically at regional level, with support arrangements in place and used by the Regional Co-ordination Group.
Regional Co-ordination Group	A group of senior representatives of all relevant principal response agencies, whose function is to facilitate strategic level co-ordination at regional level.
Rendezvous Point (RVP)	The Rendezvous Point is the location to which all resources responding to the emergency site are directed in the first instance. An Garda Síochána will organise the Rendezvous Point. Other services may have one of their officers present to direct responding vehicles into action or to that service's Holding Area.
Site Management Plan	The arrangement of the elements of a typical major emergency site, matched to the terrain of the emergency, as determined by the On-Site Co-ordination Group.
Standard Operating Procedures	Sets of instructions, covering those features of an operation that lend themselves to a definite or standardised procedure, without loss of effectiveness.

Appendix 3

RUSAL

AUGHINISH

Aughinish Alumina Ltd.

Askeaton, Co. Limerick

IPPC Licence Reg. P0035-05

Extractive Waste Classification

April 2013

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1.0 Summary

Rusal Aughinish Alumina extracts alumina from bauxite ore and disposes of the bauxite residue in an on-site facility termed the Bauxite Residue Disposal Area (BRDA). Design, operation and ultimate closure of the BRDA is regulated by the Extractive Waste Directive 2006/21/EC.

The following report examines the various wastes disposed within the Aughinish BRDA and classifies each waste according to the requirements of the European Waste Catalogue (EWC) and associated legislation. The report also explains the basis for each classification.

The report identifies that the only hazardous waste disposed in the BRDA is **'salt cake'** produced in the on-site evaporator and crystalliser unit. Its classification is EWC 01-03-07*. This material is disposed in a dedicated lined cell within the BRDA.

The other extractive wastes such as red mud, process sand (both EWC 01-03-09) and lime slaker grits (EWC 10-13-04) are classified as non-hazardous under the EWC code. As the pH of the fresh mud sent to disposal is greater than 11.5 we have conducted standard skin corrosivity test work to confirm that the elevated pH does not cause the mud to have a 'corrosive' property.

Descaling and maintenance of process vessels, bunds, ponds and conveyor galleries produced a mixed process waste. These wastes are also disposed in the BRDA.

Waste non-contaminated refractory from refurbishment of boilers and calciners and constructon and demolition waste generated on-site are designated as recovered materials in the BRDA and are used for building of internal roads (which must be raised as the BRDA height increases). This reduces the usage of imported crushed limestone from external quarries.

At times some used plant materials such as cooling tower plastic-fill are contaminated with process scale residues and are thus not suitable for recovery or disposal off-site. On these occasions we request the Agency to approve the disposal of such process scale contaminated materials within the BRDA. We propose to retain this practice on an exception basis.

2.0 Classification of bauxite residue - red mud

Red mud is the principal extractive waste arising from the Bayer process for the production of alumina. It consists predominantly of

- Earth oxides present in the raw bauxite ore that remain after the soluble alumina has been selectively leached out of the bauxite by the caustic solution employed in the Bayer process.
- Products of side reactions such as de-silication product which is silica that has dissolved and re-precipitated as sodium-aluminium-silicate compounds (sodalite and Bayer cancrinite)
- Residue of sodium hydroxide and sodium carbonate from the plant recirculating caustic stream used to dissolve the alumina from the bauxite

Washed red mud is disposed of in the on-site BRDA. The typical mineralogical analysis of red mud disposed at Rusal Aughinish is shown in Table 1 below.

Table 1. Typical red mud mineralogical analysis

Red mud				
Name	**Formula**	**% wt/wt as is**	**CAS No**	**R Phrase**
Goethite	Fe2O3.H2O	13.7	1310-14-1	Not classified
Hematite	Fe2O3	13.1	1317-60-8	Not classified
Sodalite	3(Na2O.Al2O3.2SiO2.2H2O)0.8Na2CO3.0.2Na2SO4	8.7	1344-00-9	Not classified
Bayer Cancrinite	3(Na2O.Al2O3.2SiO2)2CaCO3	4.6	No CAS no.	Not classified
Perovskite	CaTiO3	4.1	12049-50-2	Not classified
Hydrogarnet	3CaO.Al2O3.SiO2.4H2O	3.0	68131-74--8	Not classified
Gibbsite	Al2O3.3H2O	2.7	21645-51-2	R36
Rutile	TiO2	2.3	13463-67-7	R36/37/38
Diaspore (Alumina) solid solution goethite	Al2O3.H2O	2.1	1318-23-6	Not classified
Boehmite	Al2O3.H2O	1.5	1318-23-6	Not classified
Carbonate Apatite	5.2CaO.0.8Na2O.2.5CO2.P2O5	0.9	471-34-1	R36
Anatase	TiO2	0.6	1317-70-0	R20, R36/37/38
Quartz	SiO2	0.6	14808-60-7	R48/20, R40/20
Zirconium silicate	ZrSiO4	0.3	10101-52-7	R20, R36/37/38
Sodium Carbonate	Na2CO3	0.3	497-19-8	R36/37/38
Sodium Hydroxide	NaOH	0.3	1310-73-2	R35
Hydrotalcite	$Mg_6Al_2(CO_3)(OH)_{16}{\cdot}4(H_2O)$	0.1	11097-59-9	Not classified
Water	H2O	42.0		

The principal components of potential concern in red mud are quartz due to the potential for finely divided crystalline silica and sodium products due to their potential as corrosives. In the absence of significant impacts from these two components red mud is classified as non-hazardous and is listed in the EWC as 01-03-09.

The quartz levels in the Boke bauxite from Guinea and Trombetas bauxite from Brazil processed at Aughinish are relatively low (<1%) compared to some eg Australian bauxites. Thus the potential for classification of red mud as hazardous waste effectively depends on the sodium content of the mud.

1.1 Classification of red mud using the EPA Hazardous Waste Classification tool

Attachment 1 contains the Worksheets used to classify red mud based on the composition in Table 1 above. A number of issues arise when carrying out the classification exercise.

1. Some compounds identified do not have a CAS no. such as Bayer cancrinite. For others it is not absolutely clear that the compound identified by analysis of the mud matches the CAS compound exactly.

2. There are conflicting Risk-phrases for some compounds such as for iron hematite and sodalite (sodium aluminium silicate) depending on the source.

3. The CAS numbers and Safety Data Sheets generally refer the compounds isolated as pure dry chemicals. Application of the SDS and associated Risk phrases to mixtures of such compounds in a red mud matrix in paste form has the potential to over-state the risks associated.

Bearing in mind the above uncertainties we have conducted a best estimate analysis of red mud.

In the case of red mud there are two possible European Waste Catalogue (EWC) codes namely:

- 01-03-09 Red mud from alumina production other than the wastes mentioned in 01-03-07*
- 01-03-07* Other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals.

Sheet 6 in Attachment 1 of the EPA classification tool summarises the Risk phrases in each Risk category compared to the thresh-hold for each category based on the typical red mud composition in Table 1 above. The principal sources of information for Risk phrases were:

- European Commission Chemical Substances Information Systems (ESIS)
- Safety Data Sheets from Sigma Aldrich
- Safety Data sheets from other large companies in the absence of a Sigma Aldrich SDS

As can be seen the Risk categories with the potential to classify red mud as hazardous are:

- Harmful with Risk Phrase R20
- Corrosive with Risk Phrase R35
- Irritant with Risk Phrases R36/37/38
- Carcinogen Category 3

However application of the appropriate Risk Phrases to the % composition of each compound present in red mud results in a 'Not hazardous' classification (see Attachment 1).

In compiling the appropriate Risk phrase data to characterise each component of red mud two major components, iron hematite and sodalite, produced conflicting data. In the final analysis we employed

- the 'Minelco' SDS for Hematite
- an OECD SIDS (Screening Information Data Set) document published by United Nationa Environment Programme and a review by the European Food Safety Authority of the impact of sodium aluminium silicate on food

to conclude that neither of these compounds is an irritant. The fact that sodalite is a food additive known as E554 further supports the conclusion that sodalite is not an irritant.

1.2 Discussion of red mud classification as 'not hazardous'

Examination of the constituents present in red mud suggests that sodium is likely to be the most reactive and dominate any hazard characteristics of the mud. From Table 1 above it can be seen that sodium in red mud is present in three main forms viz:

- as sodium hydroxide (R35)
- as sodium carbonate (R36/37/38)
- as sodalite or Bayer cancrinite (Not classified)

The processing of bauxite to produce alumina via the Bayer process involves extraction of the alumina in a strong caustic solution. Due to the fine grained nature of red mud (d50 < 5um) it is technically difficult to recover all of the caustic solution from the mud. Thus red mud invariably contains some residual caustic and this has the potential to render the red mud hazardous if its concentration exceeds a permitted level. The caustic content of red mud is generally accepted to be the principal determinant of its hazard potential. Caustic soda is classified as an R35 corrosive. If its concentration exceeds 1% of the red mud then the mud is considered a potential corrosive material and must be classified as hazardous.

Residual caustic in red mud is in contact with the air and absorbs atmospheric CO_2 to convert to sodium carbonate. Sodium carbonate is classified as R36/37/38 irritant. If the concentration of irritant exceeds 20% in red mud then the mud would also be considered hazardous.

The process design at Rusal Aughinish is such as to ensure that the red mud is thoroughly washed prior to disposal. This is achieved by three complimentary means:

1. Only high quality bauxites with high available alumina content and a low ratio of mud to alumina are processed at Rusal Aughinish. This facilitates more efficient mud washing.
2. The mud washing circuit consists of 3 stages of counter-current mud washing with condensate followed by a further washing stage with condensate on a vacuum drum filter. This arrangement provides very efficient washing and caustic recovery and ensures that the red mud sent to the Bauxite Residue Disposal Area (BRDA) is low in caustic.
3. The Rusal Aughinish BRDA employs Dry mud disposal. This minimises the liquid content associated with mud to disposal and so minimises the caustic and carbonate content.

Most of the sodium present in red mud is bound up as solid phase sodalite or Bayer cancrinite. These are sodium aluminium silicate compounds formed within the Bayer process due to the dissolution and re-precipitation of silica. Both the UNEP SIDS review and the EFSA review of sodium-aluminium-silicate indicate that it is not an irritant. However it is observed that water washing of sodalite can release some sodium carbonate so it is necessary to conduct leaching analysis on red mud to assess the overall 'effective' sodium carbonate associated with red mud. Such leaching tests are conducted for the routine red mud analysis required by the IPPC licence (P0035-05).

Table 2 below shows the analysis of fresh red mud disposed to the BRDA during 2012 as per IPPC licence monitoring requirement. The mud is leached in water which is then analysed for total sodium (expressed as soda Na2O). The caustic content is calculated by multiplying the total soda content by the caustic:soda ratio. The caustic is then expressed as % NaOH. The non-caustic soda is assumed conservatively to be sodium carbonate (whereas it contains a little sodium chloride and sodium sulphate.) This methodology ensures that any leachable sodium carbonate from sodium aluminium silicate is included as part of the measured total sodium carbonate.

It can be seen that during 2012 the R35 caustic content of red mud ranged between 0.5 and 0.75% (dry basis). It can also be seen that the concentration of R36 sodium carbonate (liquid phase plus leachable from sodalite) was quite low and ranged between 0.1% and 0.2% (dry basis). Thus washed red mud sent to disposal at Rusal Aughinish in 2012 was indeed below the thresh-hold for classification as either 'Corrosive' or as 'Irritant'.

Table 2. Red mud leaching analysis for caustic and sodium carbonate 2012.

Emission Point Reference	Date	pH	Dry matter	Soda	Caustic/soda	Caustic	Non-caustic soda
			%	mg/Kg	%	mg/Kg	mg/Kg
				Na2O		NaOH	eq Na2CO3
						R35	R36
C.4 - Red Mud	January 12	12.3	58	6920	83.8%	7483	1917
	April 12	11.9	59	4626	83.8%	5002	1281
	July 12	11.7	58	5307	84.4%	5779	1415
	October 12	12.4	59	5685	85.0%	6235	1458
Average concentration (mg/kg)						6125	1518
Average concentration (%)						0.61	0.15

Detailed analyses of metals present in the leachate from the above mentioned mud leaching tests are shown in Table 3 below and do not suggest that there is any other parameter of concern.

Table 3. Red mud leaching analysis for metals 2012

Emission Point Reference	Date	Chloride mg/Kg	Fluoride mg/Kg	Al* mg/Kg	As* mg/Kg	Cd* mg/Kg	Cr* mg/Kg	Cu* mg/Kg	Fe* mg/Kg	Pb* mg/Kg	Mg* mg/Kg	Hg* mg/Kg	Ni* mg/Kg	Ti* mg/Kg	Zn* mg/Kg
C.4 Red Mud	January 12	33	51	22129	0.276	< 0.01	195	3.1	12092	3.9	74.0	0.0184	0.85	6654	7.5
	April 12	14	61	35308	0.459	< 10	220	2.4	362	4.6	69.6	< 0.2	0.60	4566	2.4
	July 12	27	70	12001	< 0.01	< 0.01	3	2.1	99	< 0.01	30.6	0.0044	< 0.01	89	0.6
	October 12	26	71	32790	0.063	< 10	257	2.7	10780	5.1	41.2	< 0.0002	0.71	1550	1.2

1.3 Changes to red mud post disposal in the BRDA

The analysis of red mud for IPPC purposes above is conducted on fresh red mud prior to its deposition in the BRDA.

A new process termed mud farming is under development at Rusal Aughinish. It consists of compacting and then ploughing and harrowing the mud surface to convert as much as possible of the residual R35 caustic to more benign R36 sodium carbonate via enhanced atmospheric carbonation. This carbonation process also reduces the pH of the mud. Figure 1 below shows the reduction of causticity (caustic/(caustic+carbonate)) and pH due to ploughing of the BRDA surface. This effect combined with:

a. rain water washing in wet weather and
b. dust control sprinkler operation in dry weather

further reduces the potential for the mud to be a corrosive or an irritant.

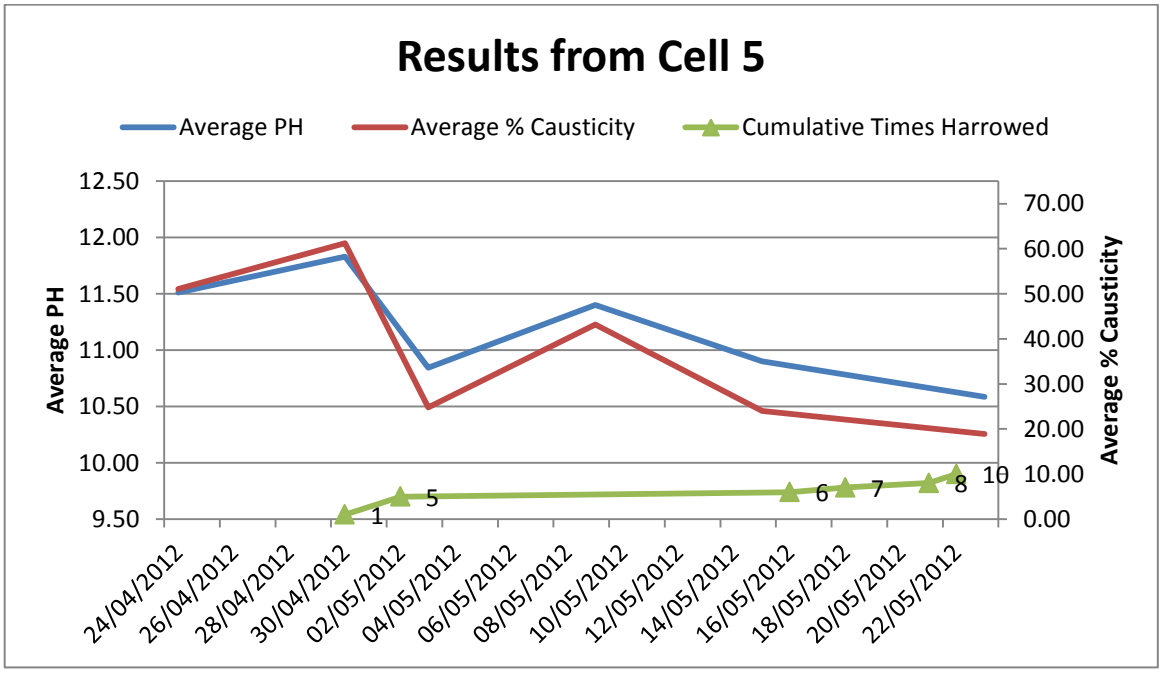


Figure 1 Reduction of causticity and pH via mud farming

1.4 Red mud leachate analysis

Leachate and rainwater run-off from the Rusal Aughinish BRDA not required for re-use in the Alumina refinery are neutralised, clarified and disposed to the river Shannon via the licenced effluent outfall W1-1. This effluent is tested twice per year for toxicity to marine organisms. Test results for 2012 are shown in Table 4 below. The toxicity results are always low ie at limit of detection which supports the assertion that BRDA leachate does not contain any chemical that would cause the Rusal Aughinish BRDA to be classified as hazardous.

Table 4. BRDA run-off effluent - toxicity testing results 2012

Test Parameter	June 2012 Results (TU)	December 2012 Results (TU)	ELV (TU)
48h LC_{50} to *Tisbe battagliai*	< 3.1	< 3.1	5
30 min EC_{50} to *Vibrio fischeri*	< 2.2	< 2.2	5

Note: Values denoted less than (<) are below the relevant threshold or limit of detection for that test

1.5 Mud characterisation for 'Corrosive' property

Rusal Aughinish has commissioned two sets of mud corrosivity tests

1. On BRDA farmed mud (2011)
2. On fresh mud (2013)

The results are summarised in the Table below. Each of the tests returned a 'not corrosive' result.

Table 5. Red mud 'Corrosivity' tests

Farmed mud	**Amphirolled mud**	**Amphirolled & Carbonated mud**	**BRDA Leachate**
Caustic eq Na2CO3 gpl	29.4	3.4	4.5
Causticity	89.2	57	58.2
pH	12.8	11.1	12.2
OECD 431	Not corrosive	Not corrosive	Not corrosive
Fresh mud			
Soda eq Na2O gpl	6.1	10.1	16.3
Causticity	85.6	89.9	90.8
pH	13.0	13.2	13.1
OECD 431	Not corrosive	Not corrosive	Not corrosive

1.6 Testing of red mud at other EU Refineries

The European Aluminium Association has canvassed EU alumina refineries to determine the outcomes of laboratory testing of their red muds for 'Corrosive' and/or 'Irritant' properties. The findings of this test work were shared recently and were in summary:

- Of the 3 samples from one other plant tested for 'H8 Corrosive' none was found to be corrosive.
- Of the 9 samples from 3 other plants tested for H4 'Skin Irritant' just 1 (a high pH fresh mud sample) returned a result as a 'Skin Irritant'.
- Of the 6 samples from 2 other plants tested for H4 'Eye Irritant' none was classified as such.

A listing of these tests and findings is shown in Table 6 below.

Table 6. Red mud sampling results from various EU alumina refineries

Sample type	pH*	Test	Test result	Test lab
Deposited and amphirolled	12,8	OECD 431	Not corrosive	CERB, France
Amphirolled and farmed	11,1	OECD 431	Not corrosive	CERB, France
Leachate	12,2	OECD 431	Not corrosive	CERB, France
Fresh from filter press	11,8	OECD 431	Not corrosive	CERB, France
Aged material	11,0	OECD 431	Not corrosive	CERB, France
Intermediate material	11,5	OECD 431	Not corrosive	CERB, France
Fresh from filter press	11,8	OECD 439	No skin irritation	CiTox, Hungary
Aged material	11,0	OECD 439	No skin irritation	CiTox, Hungary
Intermediate material	11,5	OECD 439	No skin irritation	CiTox, Hungary
Fresh from filter press	11,8	OECD 438	No eye irritation	CiTox, Hungary
Aged material	11,0	OECD 438	No eye irritation	CiTox, Hungary
Intermediate material	11,5	OECD 438	No eye irritation	CiTox, Hungary
Fresh from filter press	11,8	OECD 404	No skin irritation	CiTox, Hungary
Aged material	11,0	OECD 404	No skin irritation	CiTox, Hungary
Intermediate material	11,5	OECD 404	No skin irritation	CiTox, Hungary
Fresh from filter press	11,8	OECD 405	Mildly irritant to eyes, reversible in 48 hours – no classification	CiTox, Hungary
Aged material	11,0	OECD 405	No eye irritation	CiTox, Hungary
Intermediate material	11,5	OECD 405	Mildly irritant to eyes, reversible in 24 hours – no classification	CiTox, Hungary
Sample type	**pH**	**Test**	**Test result**	**Test lab**
Sample	11,4	OECD 404	No skin irritation	Army Centre for Medical Research, Ro

Sample	11,8	OECD 404	No skin irritation	ACMR, Ro
Sample	12,4	OECD 404	No skin irritation	ACMR, Ro
Sample	11,4	OECD 405	No eye irritation	AMCR, Ro
Sample	11,8	OECD 405	No eye irritation	AMCR, Ro
Sample	12,4	OECD 405	Mildly irritant to eye, reversible in 24 hours - no classification	AMCR, Ro
Sample	12,6	OECD 404	No irritation	Interlab, Spain
Sample	12,7	OECD 404	No irritation	Interlab, Spain
Sample	13,2	OECD 404	Skin irritation	Interlab, Spain

1.7 Other evidence that elevated pH is not a problem

A pH of 11.5 is considered as a potential trigger for a substance to be corrosive. In our experience washed red mud sent to disposal is closer to pH 13 but does not cause corrosive type problems to operators and craftspeople working with red mud handling equipment. Based on open literature a number of well known skin creams and oils also have pH above 12.0. Attachment 2 contains a published paper from the 'International Journal of Dermatology' that shows the range of pH in skin care products. Some well-known skin care products have pH greater than 12. This paper is useful to put the pH of red mud into context.

1.8 Conclusion

Rusal Aughinish red mud is not corrosive because it is thoroughly washed prior to disposal to the Bauxite Residue Disposal Area (BRDA). Tests conducted on Aughinish red mud and leachate confirm the absence of a corrosive property.

The processes of:

a. mud farming to carbonate residual caustic
b. water showering in dry weather to prevent dusting
c. rainfall in wet weather

further reduce its potential as a corrosive or an irritant. For these reasons Rusal Aughinish red mud is not hazardous. These findings are mirrored in the other EU alumina plants.

3.0 Classification of bauxite residue – process sand

Approximately 5% of the bauxite residue after alumina extraction reports as a granular material (150-1000 um) and is termed process sand. This material is removed from the process before the mud circuit, is washed with condensate and is trucked to the BRDA. It is used for construction of internal roads in the BRDA.

The typical analysis of process sand is shown in Table 7 below.

Table 7. Process sand mineralogical composition

Mineral Form	Chemical Fomula	% wt/wt as is	CAS No	R Phrase
Goethite	Fe2O3.H2O	29.8	1310-14-1	Not classified
Hematite	Fe2O3	24.4	1317-60-8	Not classified
Boehmite	Al2O3.H2O	8.8	1318-23-6	Not classified
Sodalite	3(Na2O.Al2O3.2SiO2.2H2O)0.8Na2CO3.0.2Na2SO4	3.9	1344-00-9	R36/37/38
Hydrogarnet	3CaO.Al2O3.SiO2.4H2O	3.7	68131-74--8	Not classified
Diaspore solid solution goethite	Al2O3.H2O	2.8	1318-23-6	Not classified
Perovskite	CaTiO3	2.1	12049-50-2	Not classified
Rutile	TiO2	1.2	13463-67-7	R36/37/38
Quartz	SiO2	1.0	14808-60-7	R48/20, R40/20
Carbonate Apatite	5.2CaO.0.8Na2O.2.5CO2.P2O5	1.0	471-34-1	R36
Sodium Hydroxide	NaOH	0.3	1310-73-2	R35
Sodium Carbonate	Na2CO3	0.2	497-19-8	R36/37/38
Zirconium silicate	ZrSiO4	0.1	10101-52-7	R20, R36/37/38
Water	H2O	20.0		

2.1 Classification of process sand using EPA Hazardous Waste Classification tool.

Attachment 3 contains the Worksheets used to classify process sand based on the sand composition in Table 7 above. Again the issue of conflicting Risk-phrases for some compounds such as iron hematite and sodalite arise when carrying out the classification exercise.

As in the case of red mud there are two potential European Waste Catalogue (EWC) codes namely:

- 01-03-09 Red mud from alumina production other than the wastes mentioned in 01-03-07*
- 01-03-07* Other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals.

Attachment 3 Sheet 6 of the EPA classification tool summarises the Risk phrases in each Risk category compared to the thresh-hold for each category based on the process sand composition in Table 7 above. As can be seen the Risk categories with the potential to classify red mud as hazardous are:

- Corrosive with Risk Phrase R35
- Irritant with Risk Phrases R36/37/38
- Carcinogen Category 3

However application of the appropriate Risk Phrases to the % composition of each compound present in process sand results in a 'Not hazardous' classification.

2.2 Process sand does not contain dangerous levels of caustic or sodium carbonate

The full sand analysis in Table 7 above and the 2012 process sand waste leaching data in Table 8 below compiled for IPPC license reporting demonstrate that process sand caustic concentration was less than the 1% corrosive trigger during 2012. They also confirm that the concentration of sodium carbonate was low compared to the 20% irritant trigger level. On this basis process sand is not a corrosive or an irritant.

As with red mud the leaching analysis of process sand for metals in Table 9 below does not suggest any basis for classifying the sand as a hazardous waste due to its metals content.

Table 8. Process sand caustic and sodium carbonate content 2012

Emission Point Reference	Date	pH	Dry matter	Soda	Caustic/soda	Caustic	Non-caustic soda
			%	mg/Kg	%	mg/Kg	mg/Kg
				Na2O		NaOH	eq Na2CO3
						R35	R36
C.4 - Sand	January 12	12.2	81	4832	83.8%	5225	1338
	April 12	11.8	81	3751	83.8%	4056	1039
	July 12	12.3	82	3716	84.4%	4047	991
	October 12	12.2	81	3419	85.0%	3750	877
Average concentration (mg/kg)						4269	1061
Average concentration (%)						0.43	0.11

Table 9. Process sands metals analysis 2012

Emission Point Reference	Date	Chloride	Fluoride	Al*	As*	Cd*	Cr*	Cu*	Fe*	Pb*	Mg*	Hg*	Ni*	Ti*	Zn*
		mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
C.4 - Sand	January 12	18	50	12520	0.864	< 0.01	152.7	2.06	33386	6.50	324	0.021	2.332	1859	3.96
	April 12	7	40	12066	0.756	< 10	131.8	88.41	1623	5.23	230.8	< 0.2	0.695	1736	2.95
	July 12	40	45	10092	< 0.01	< 0.01	105.5	1.20	18993	4.98	264.1	< 0.0002	0.52	805.20	2.64
	October 12	6	37	8754	< 10	< 10	44.4	1.47	14795	5.70	254.54	< 0.0002	0.700	74.97	3.07

2.3 Conclusion

Rusal Aughinish process sand is neither a corrosive nor an irritant because it is thoroughly washed prior to disposal to the BRDA. Waste leaching tests conducted on process sand confirm the absence of a corrosive or irritant character. For this reason process sand is classified as non-hazardous.

4.0 Classification of lime grits (from slaking of burnt lime)

Approximately 10% of burnt limestone does not convert to CaO during the limestone burning process. When burnt lime is subsequently slaked in water this fraction of burnt limestone does not slake and is rejected after the slaker as stones and grits. The mineralogical analysis of this waste is shown in Table 10 below.

Table 10. Lime grit mineralogical analysis

Mineral Form	Chemical Fomula	% wt/wt as is	CAS No	R Phrase
Calcium carbonate	CaCO3	78.3	471-34-1	Not applicable to stones
Kaolin	Al2O3.2SiO2.2H2O	5.0	1332-58-7	No R phrase
Milk of lime	Ca(OH)2	2.7	1305-62-0	R34, R41
Quartz	SiO2	2.0	14808-60-7	R48/20, R40/20
Magnesium carbonate	MgCO3	1.1	23389-33-5	No R phrase
Rutile	TiO2	0.2	13463-67-7	R36/37/38
Water	H2O	10.0		

Limestone grits are listed in the EWC directly as EWC Code 10-13-04 and described as 'wastes from calcination and hydration of lime'.

On the basis that lime grits at Rusal Aughinish are produced from conventional water slaking of industrial burnt lime the above EWC code applies directly to the rejected limestone from our lime slaking process. We do not propose to examine the issue any further.

5.0 Classification of salt-cake

The use of caustic (NaOH) to extract alumina from bauxite in the cyclic Bayer process results in an accumulation of various sodium salt impurities in the circulating caustic stream. These impurities such as sodium carbonate, sodium sulphate and sodium organates would impede the efficient operation of the process if permitted to accumulate excessively. To maintain control of these impurities a small side-stream of process caustic is continuously evaporated and then cooled to cause the sodium impurities to crystallise and salt-out. The product of this side-stream is termed 'salt cake'.

Table 11. Analysis of the salt-cake is shown in Table 11 below.

Mineral Form	Chemical Fomula	% wt/wt as is	CAS No	R Phrase
Sodium aluminate	$NaAlO_2$	15.4	1302-42-7	R35
Sodium oxalate	$Na_2C_2O_4$	15.3	62-76-0	R21/22, R38
Sodium hydroxide	NaOH	10.3	1310-73-2	R35
Sodium humates	Na-C	7.7	Not known	R36/37/38 (estimate)
Sodium carbonate	Na_2CO_3	3.3	497-19-8	R36/37/38
Sodium sulphate	Na_2SO_4	0.2	7757-82-6	R36
Sodium vanadate	Na_3VO_4	0.1	13721-39-6	R23/24/25
Water		44.0		

Sheet 6 in Attachment 4 of the EPA classification tool summarises the Risk phrases in each Risk category compared to the thresh-hold for each category based on the salt-cake composition in Table 11 above. As more than 25% of the salt cake product is R35 the waste is clearly a corrosive material and accordingly is classified as hazardous waste. The appropriate EWC code is:

01-03-07* 'Other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals'.

Salt cake waste is stored in a segregated lined cell within the BRDA.

6.0 Classification of process scales/wastes from maintenance & cleaning

The principal other extractive waste disposed in the BRDA is the waste generated from the descaling and cleaning of process vessels, bunds, ponds and conveyor galleries. It includes red mud, process sand, alumina hydrate and alumina as well as mixed process scales. This material is transported to the BRDA by truck and tipped at the designated tipping point. It is then bulldozed to its final location. Table 12 below lists the component wastes in this category.

Table 12. Process scales and vessel cleaning wastes

Material	Normal EWC code	Possible alternative code	Comment
Scales	01-03-99	01-03-07*	Mainly red side of plant
Red mud	01-03-09	01-03-07*	If mud not fully washed
Process sand	01-03-09	01-03-07*	Used for internal road construction
Alumina hydrate	01-03-08	01-03-07*	If not feasible to recycle
Alumina	01-03-08		Not feasible to recycle

This category of process waste is classified normally non-hazardous. If contaminated with caustic above the 1% thresh-hold level it would be classified as hazardous 01-03-07* and would be managed similarly to the principal hazardous waste - salt cake.

7.0 Other non-process recovered materials utilised in the BRDA

Operating high temperature plant such as boilers and calciners invariably entails the use of refractory materials. This generates refractory waste during equipment overhauls. Used refractory is not recycleable but is suitable for the construction of internal roads in the BRDA. We propose to continue to extract value from the waste refractory provided that it is not contaminated with Vanadium.

Development activities within the plant periodically generate Construction and Demolition waste. At present this is also employed for road construction within the BRDA. We propose to continue this practice.

Maintenance activities generate waste metal or plastic and waste refractory material that is normally transported off-site for recycling or for recovery. From time to time some such wastes are contaminated with process scale which renders them unsuitable for disposal off-site and the practice is to dispose of them in the BRDA with Agency approval. We propose to maintain this practice and recover any such waste for road building within the BRDA. We will report on the quantities involved in the usual manner via the Annual Environmental Report.

Table 13 Other recovered materials utilised in the BRDA

Material	Normal EWC code	Possible alternative code	Comment
Refractory	16-11-04		Used for internal road construction
Concrete	17-01-01		Construction and demolition
Bricks	17-01-02		Construction and demolition
Insulation materials	17-06-02		Pipework and tank insulation
Metals	20-01-06		Process pipes and metal sheet
Plastic	20-01-04		eg Cooling tower fill

Attachment 1 – Red mud hazard classification

Hazardous Waste Classification Worksheet (Revised 31st August 2004)

Box No.	Information Required	Information	
	Company Details		
A	**Company Name**	AUGHINISH ALUMINA LTD.	
	Company Address	AUGHINISH ISLAND, ASKEATON CO. LIMERICK	
	Date	20 - APRIL - 2013	
	IPC or Waste License Number (if applicable)	P0035-05	
	Contact Person	LIAM FLEMING	
	Waste Description	BAUXITE RESIDUE - RED MUD	
	European Waste Catalogue/Hazardous Waste List		
B	**Possible EWC Codes**		Asterisk Yes / No
		01 03 09	☐ / ☑
		01 03 07 *	☐ / ☐
			☐ / ☐
			☐ / ☐
			☐ / ☐
			☐ / ☐
C	**Six-Digit EWC Code**	01 03 07 *	Asterisk Yes / No ☑ / ☐
D	**EWC Description**	OTHER WASTES CONTAINING DANGEROUS SUBSTANCES FROM PHYSICAL AND CHEMICAL PROCESSING OF METALLIFEROUS MINERALS	
C1	***Mirror Entry Code (if applicable)***	01 03 09	Asterisk Yes / No ☐ / ☐
D1	***Mirror Entry Description (if applicable)***	RED MUD FROM ALUMINA PRODUCTION OTHER THAN THE WASTES MENTIONED IN 01-03-07 *	
E	**Is this waste classified as hazardous waste according to HWL?**	Mirror Entry	☑
		No	☐
		Yes	☐

Hazardous Waste Classification Worksheet (Revised 31st August 2004)

Category I Waste (Box F)	
[] 1.	Anatomical substances, hospital or other clinical waste.
[] 2.	Pharmaceutical, medic inal or veterinary compounds.
[] 3.	Wood preservatives.
[] 4.	Biocides or phyto-pharmaceutical substances.
[] 5.	Residue from substances employed as solvents.
[] 6.	Halogenated organic substances not employed as solvents, excluding inert polymerized materials.
[] 7.	Tempering salts containing cyanides.
[] 8.	Mineral oils or oily substances (including cutting sludges).
[] 9.	Mixtures or emulsions of oil and water or hydrocarbon and water.
[] 10.	Substances containing polychlorinated biphenyls or polychlorinated terphenyls (including dielectrics).
[] 11.	Tarry materials arising from refining, distillation or any pyrolytic treatment (including still bottoms).
[] 12.	Inks, dyes, pigments, paints, lacquers or varnishes.
[] 13.	Resins, latex, plasticizers, glues or adhesives.
[] 14.	Chemical substances arising from research and development or teaching activities (including laboratory residues) which are not identified or are new and whose effects on humans or the environment are not known.
[] 15.	Pyrotechnics or other explosive materials.
[] 16.	Photographic chemicals or processing materials.
[] 17.	Any materia l contaminated with any congener of polychlorinated dibenzo-furan.
[] 18.	Any material contaminated with any congener of polychlorinated dibenzo-p-dioxin.

Category II Waste (Box G)	
[] 19.	Animal or vegetable soaps, fats or waxes.
[] 20.	Non-halogenated organic substances not employed as solvents.
[] 21.	Inorganic substances without metals or metal compounds.
[] 22.	Ashes or cinders.
[] 23.	Soil, sand or clay (including dredging spoils).
[] 24.	Non-cyanidic tempering salts.
[] 25.	Metallic dust or powder.
[] 26.	Spent catalyst materials.
[✓] 27.	Liquids or sludges containing metals or metal compounds.
[] 28.	Residue (other than scrubber sludges, sludges from water purification plants and sewage sludges (untreated or unsuitable for use in agriculture)) from pollution control operations (including baghouse dusts).
[] 29.	Scrubber sludges.
[] 30.	Sludges from water purification plants.
[] 31.	Decarbonization residue.
[] 32.	Ion-exchange column residue.
[] 33.	Sewage sludges, untreated or unsuitable for use in agriculture.
[] 34.	Residue from cleaning of tanks or equipment.
[] 35.	Contaminated equipment.
[] 36.	Contaminated containers (including packaging and gas cylinders).
[] 37.	Batteries or other electrical cells.
[] 38.	Vegetable oils.
[] 39.	Materials resulting from the selective collection of waste from households.
[] 40.	Any other waste.

Category II Constituents (Box H)	
[ ] 41.	Beryllium or beryllium compounds.
[ ] 42.	Vanadium compounds.
[ ] 43.	Chromium (VI) compounds.
[ ] 44.	Cobalt compounds.
[ ] 45.	Nickel compounds.
[ ] 46.	Copper compounds.
[ ] 47.	Zinc compounds.
[ ] 48.	Arsenic or arsenic compounds.
[ ] 49.	Selenium or selenium compounds.
[ ] 50.	Silver compounds.
[ ] 51.	Cadmium or cadmium compounds.
[ ] 52.	Tin compounds.
[ ] 53.	Antimony or antimony compounds.
[ ] 54.	Tellurium or tellurium compounds.
[ ] 55.	Barium compounds, excluding barium sulphate.
[ ] 56.	Mercury or mercury compounds.
[ ] 57.	Thallium or thallium compounds.
[ ] 58.	Lead or lead compounds.
[ ] 59.	Inorganic sulphides.
[ ] 60.	Inorganic fluorine compounds, excluding calcium fluoride.
[ ] 61.	Inorganic cyanides.
[ ] 62.	Any of the following alkaline or alkaline earth metals, namely, lithium, sodium, potassium, calcium, magnesium in uncombined form.
[ ] 63.	Acidic solutions or acids in solid form.
[✓] 64.	Basic solutions or bases in solid form.
[ ] 65.	Asbestos (dust or fibres).
[ ] 66.	Phosphorus: phosphorus compounds, excluding mineral phosphates.
[ ] 67.	Metal carbonyls.
[ ] 68.	Peroxides.
[ ] 69.	Chlorates.
[ ] 70.	Perchlorates.
[ ] 71.	Azides.
[ ] 72.	Polychlorinated biphenyls or polychlorinated terphenyls.
[ ] 73.	Pharmaceutical or veterinary compounds.
[ ] 74.	Biocides or phyto-pharmaceutical substances (including pesticides).
[ ] 75.	Infectious substances.
[ ] 76.	Creosotes.
[ ] 77.	Isocyanates or thiocyanates.
[ ] 78.	Organic cyanides (including nitriles).
[ ] 79.	Phenols or phenol compounds.
[ ] 80.	Halogenated solvents.
[ ] 81.	Organic solvents, excluding halogenated solvents.
[ ] 82.	Organohalogen compounds, excluding inert polymerized materials and other substances referred to in this Part.
[ ] 83.	Aromatic compounds; polycyclic and heterocyclic organic compounds.
[ ] 84.	Aliphatic amines.
[ ] 85.	Aromatic amines.
[ ] 86.	Ethers.
[ ] 87.	Substances of an explosive character, excluding those referred to elsewhere in this Part.
[ ] 88.	Sulphur organic compounds.
[ ] 89.	Any congener of polychlorinated dibenzo-furan.
[ ] 90.	Any congener of polychlorinated dibenzo-p-dioxin.
[ ] 91.	Hydrocarbons and their oxygen, nitrogen or sulphur compounds not otherwise referred to in this Part.

Box I: Property Test Results and Waste Classification					
Property	**Property Testing**			**Waste Classification**	
	Test Code	**Title of Test**	**Results**	**Hazard (s)**	**Risk Phrase (s)**
Explosive					
Oxidising					
Flammable					
Irritant/ Corrosive	B40 OECD 431	IN VITRO SKIN CORROSION HUMAN SKIN MODEL TEST	NOT CORROSIVE (NOT H8)	NONE	NONE
Harmful/Toxic					
Carcinogenic					
Infectious	No test methods available for this property				
Toxic for Reproduction					
Mutagenic					
Ecotoxic					
Residuary hazardous property					

Red mud

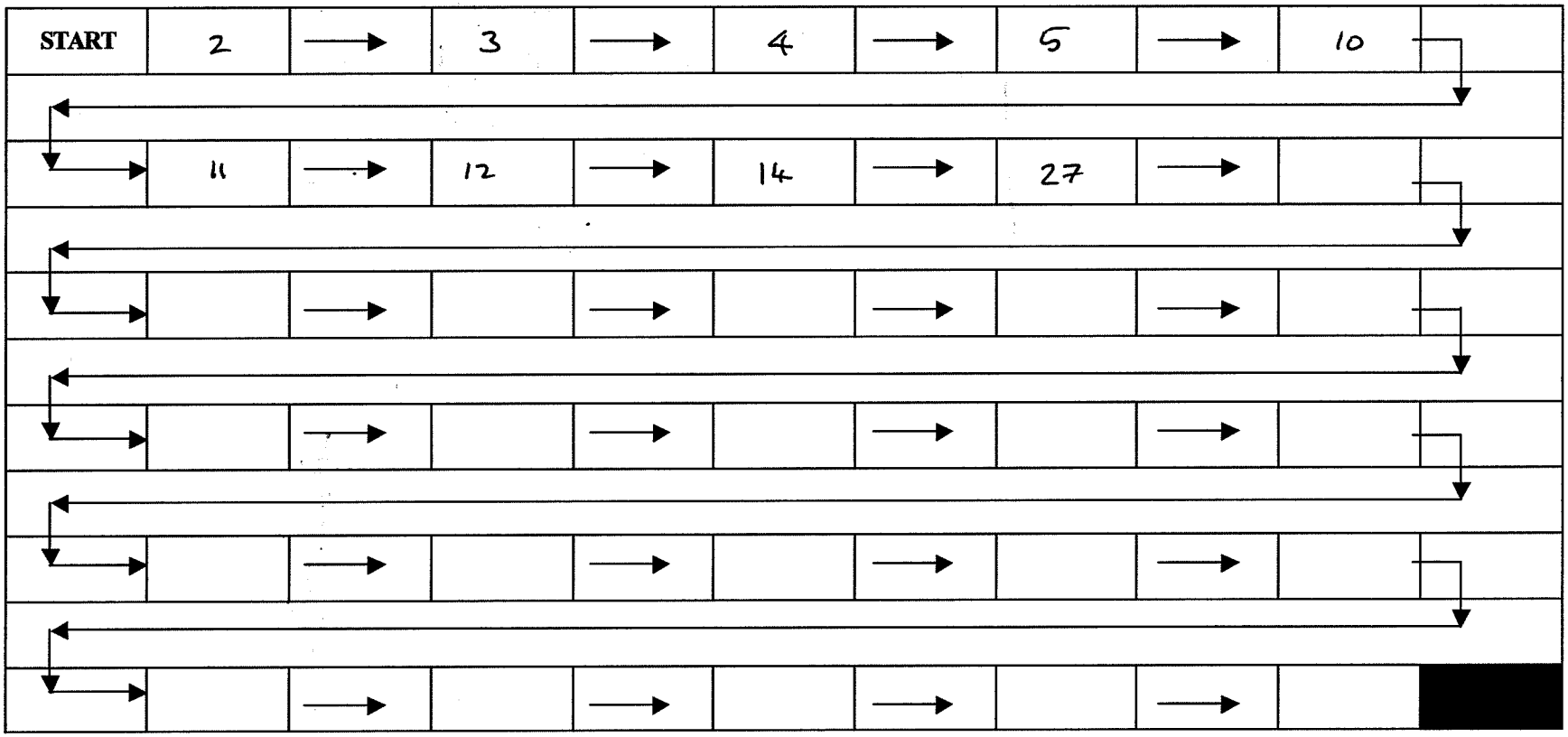
Name	Formula	% wt/wt as is	CAS No	R Phrase	Reference	Carcinogen group	Toxic for reproduction	Mutagenic category
Goethite	Fe2O3.H2O	13.7	1310-14-1	Not classified	ESIS & Sigma Aldrich SDS	-	-	-
Hematite	Fe2O3	13.1	1317-60-8	Not classified	ESIS & Minelco SDS	-	-	-
Sodalite	3(Na2O.Al2O3.2SiO2.2H2O)0.8Na2CO3.0.2Na2SO4	8.7	1344-00-9	Not classified	ESIS & Sigma Aldrich SDS	-	-	-
Bayer Cancrinite	3(Na2O.Al2O3.2SiO2)2CaCO3	4.6	No CAS no.	Not classified	As for sodalite	-	-	-
Perovskite	CaTiO3	4.1	12049-50-2	Not classified	Sigma Aldrich SDS	-	-	-
Hydrogarnet	3CaO.Al2O3.SiO2.4H2O	3.0	68131-74--8	Not classified	Rocktron SDS	-	-	-
Gibbsite	Al2O3.3H2O	2.7	21645-51-2	R36/37/38	ESIS & Sigma Aldrich SDS	-	-	-
Rutile	TiO2	2.3	13463-67-7	R36/37/38	ESIS & Sigma Aldrich SDS	-	-	-
Diaspore (Alumina) solid solution goethite	Al2O3.H2O	2.1	1318-23-6	Not classified	As per boehmite	-	-	-
Boehmite	Al2O3.H2O	1.5	1318-23-6	Not classified	ESIS & Nabaltec SDS	-	-	-
Carbonate Apatite	5.2CaO.0.8Na2O.2.5CO2.P2O5	0.9	471-34-1	R36	Sciencelab SDS (CaCO3)	-	-	-
Anatase	TiO2	0.6	1317-70-0	R20, R36/37/38	ESIS & Guidechem.com SDS	-	-	-
Quartz	SiO2	0.6	14808-60-7	R48/20, R40/20	ESIS & U.S. Silica Co. SDS	3	-	3
Zirconlum silicate	ZrSiO4	0.3	10101-52-7	R20, R36/37/38	ESIS & Chemical Book SDS	-	-	-
Sodium Carbonate	Na2CO3	0.3	497-19-8	R36/37/38	ESIS & Sigma Aldrich SDS	-	-	-
Sodium Hydroxide	NaOH	0.3	1310-73-2	R35	ESIS & Sigma Aldrich SDS	-	-	-
Hydrotalcite	$Mg_6Al_2(CO_3)(OH)_{16}{\cdot}4(H_2O)$	0.1	11097-59-9	Not classified	Sigma Aldrich SDS	-	-	-
Water	H2O	42.0				-	-	-

Hazardous Waste Classification Worksheet (Revised 31st August 2004)

Box K : Waste Composition Details		
Properties with thresholds (Box K1)		
Property	**Threshold (% w/w)**	**Total (% w/w) in Waste**
Flash Point ≤ 55°C		0 %
Very Toxic	≥ 0.1	0%
Toxic	≥ 3	0 %
Harmful	≥ 25	1·5%
Corrosive with Risk Phrase R35	≥ 1	0·3 %
Corrosive with Risk Phrase R34	≥ 5	0 %
Irritant with Risk Phrase R41	≥ 10	0 %
Irritant with Risk Phrases R36, R37, R38	≥ 20	7·1 %
Carcinogen Category 1 or 2	≥ 0.1	0%
Carcinogen Category 3	≥ 1	0·6 %
Toxic for Reproduction Category 1 and 2 with Risk Phrases R60, R61	≥ 0.5	0 %
Toxic for Reproduction Category 3 with Risk Phrases R62, R63	≥ 5	0 %
Mutagenic Category 1 and 2 with Risk Phrase R46	≥ 0.1	0 %
Mutagenic Category 3 with Risk Phrase R40	≥ 1	0·6 %
Properties without thresholds (Box K2)		
Property		**Total (% w/w) in Waste**
Explosive		0
Oxidising		0
Infectious		0
Ecotoxic		0
Residuary hazardous property		0

Final EWC Code		
L	Final EWC Code	0 1 0 3 0 9
M	Final EWC Description	RED MUD FROM ALUMINA PRODUCTION OTHER THAN WASTES AS 01-03-07 *

Box N - Route Map - Insert the tab numbers as you are directed to them (not applicable to computer tool)



Attachment 2 - Correlation between pH and irritant effect on skin

Report

Correlation between pH and irritant effect of cleansers marketed for dry skin

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Abstract

Background Although it is important that dermatologists and the general population know the irritation potential of products marketed for dry skin used for body cleansing, this information is not usually available.

Objective To assess the irritative effect of different soaps and liquid cleansers recommended for sensitive skin. To study the correlation of the irritation effect of each substance with its pH and with the presence or absence of syndet in the product.

Methods Seventeen products marketed for dry skin and 12 common soaps used by the general population were studied. Fresh soap emulsions (8%) were applied to the volar side of the right forearm of 30 individuals with sensitive skin for 5 consecutive days using aluminum chambers. The appearance of irritation (erythema, scaling and fissures) was recorded, scored, and expressed in an Irritation index (IrIn). The pH of each solution was measured.

Results Products with a low IrIn were White Dove™ (Dove, Lever Pond's, Toronto, Ontario, Canada), Dove Baby™, Cetaphil™ (bar) (Cetaphil, Gulderma Lab., Forth Worth, TX, USA), Dove liquid cleanser for hands™, Dove pink™, and Aderma™ (Adenma, Pierre Fabre, Dermo-Cosmetique, Boulagne, France). Most corresponded to syndet products. Among the most used brand-name soap, Camay Classic™ (Camay, Procter & Gamble de Mexico, México, U.F.) had the lowest IrIn. Dove Baby™ was the only product with a neutral pH. A significant correlation between pH and the IrIn of cleansers was found ($P < 0.006$).

Conclusions Most products recommended for sensitive skin have a considerable irritation effect, which is related to the pH of the product. Better regulation of advertisement specifications including the pH level and type of cleanser contained is necessary for the majority of soaps and cleansers.

Introduction

Soaps are important for healthcare professionals in preventing the spread of infectious diseases.[1] However, the main purpose of soap is lost when these substances induce skin irritation and injury.

Most soaps and detergents are alkaline and induce an increase in cutaneous pH, which affects the physiologic protective "acid mantle" of the skin by decreasing the fat content.[2] In addition, repeated washings with soap may reduce the normal skin flora, leading to an increased colonization of the skin with coagulase-negative staphylococci; this effect has been linked to the shift in skin pH caused by soaps.[3] Lastly, it has been found that applying agents that specifically inhibit gram-positive cocci, such as antibacterial soap, generally increases gram-negative rods.[4]

Recently, a new generation of cleansers (synthetic detergents or syndets) has emerged. Syndets with a pH approximately 5.5 seem to be specially relevant because they do not modify skin pH.[5] However, the majority of soap bars and liquid detergents available on the market are a mixture of soap and syndet.[6]

Disruption of stratum corneum and changes in pH are key elements in the induction of irritant contact dermatitis and pruritus by soaps. These conditions are exacerbated in the winter months in patients with dry, sensitive skin.

The aim of this study was to assess the irritation effect of a group of bar soaps and liquid cleansers recommended for dry skin and to correlate the irritation effect of each product with their pH.

Materials and Methods

Subjects

The irritation effect of the soaps and cleansers was assessed using 30 healthy volunteers (15 female and 15 male), ranging in age from 18 to 41 years (mean 24 years), who were free of skin or systemic diseases. These individuals had a positive patch test for 1.0%

sodium lauryl sulfate (SLS), which is considered a useful substance in identifying sensitive skin.[7–10] Although the commonest form of sensitive skin is sensory (symptomatic irritant response), the correlation of such a manifestation type (burning, stinging) with conventional irritation is inconsistent.[11] So, we decided to identify individuals with sensitive skin by using the standard patch test with SLS.[12] This study was approved by our institutions Bioethics Committee, and all subjects gave their written consent.

Definition of the soaps commonly used by the general population

Three hundred subjects were interviewed about the brand-name soap of their personal use.

Soap emulsions

We prepared 8% emulsions[13] in tap water of 27 soap bars: 15 recommended for sensitive skin and 12 corresponding to soaps most used by people attending our hospital. Two undiluted liquid cleansers recommended for dry skin were also evaluated. Deionized water was used as a negative control.[14] Each solution was poured into a dark flask and identified by a number. The clinicians performing the irritation test did not know the product code.

Determination of pH

The pH of each emulsion was recorded using the Chemcadet pH meter (Cole-Parmer Instrument Co., Chicago, IL).

Irritation test

0.50 ml of each soap emulsion or liquid cleanser was applied to a disc of absorbent Whatman paper 6 mm in diameter and 1.0 mm thick. These discs were fitted into round flat aluminum chambers (Epitest Ltd, Oy, Finland), which were fixed to the volar side of the right forearm of each subject.
Exposure time to the soaps lasted for 5 days; the first for 24 h, beginning on Monday morning; then fresh solutions were applied to the same site for 6 h daily for the next 4 days. The minimum interval among applications was 12 h. After daily removal of the material, the skin was cleansed with running water and gently dried with a paper towel. The use of cream, oils or any other kind of soap on the treated skin was avoided.[15–18]
The treated site was observed every day, 1 h after the removal of the chambers, and the final evaluation was made on the Monday morning following the removal of the chambers on the previous Friday afternoon. This schedule was specifically designed for soaps and is not suitable for other irritants;[13] however, it has been used to evaluate other types of skin care products.[19]

Evaluation

The irritation effect of soaps was evaluated by three "blinded" independent clinicians.

Measurements

Skin irritation was scored as follows:

Erythema (E)
0 None
1+ Speckling moderate
2+ Uniform moderate
3+ Intense
4+ Intense (red hot) with edema

Scaling (S)
0 None
1+ Fine
2+ Moderate
3+ Intense with large scales

Fissure formation (F)
0 None
1+ Fine
2+ Pronounced unique or multiple
3+ Wide with hemorrhage or exudation

The average of the erythema, scaling and fissure values was obtained for each substance, and its sum was considered as the irritation index (IrIn). A soap was considered as a mild irritant when its IrIn was below or near to 1.0.[13]

Irritant postinflammatory hyperpigmentation was also assessed and registered as present or absent.

When the statistical analysis was completed, the name of every soap or skin cleanser was disclosed. The study was carried out in winter (average temperature 14 °C).

Statistical analysis

Statistical analysis was performed using the Kruskal–Wallis one-way analysis of variance with all pairwise comparison procedures (Dunn's and Neuman-Keuls method).

Results

Commonly used soaps by the general population

The majority of the general population interviewed (42.5%, Table 1) preferred some kind of Zest™ soap (herbal, citrus sport, neutral or aqua). Palmolive™ was the second most used brand-name soap (18.5%), and Dove™ was in third place (11.5%).

Irritant effect

Six products had IrIn values around 1.0 and were considered as nonaggressive or nonirritant: White Dove™, Dove Baby™, Cetaphil ™ (bar), Dove liquid cleanser for hands™, Dove pink™ and Aderma™. All other products had a high IrIn ranging from 2.599 to 5.426 (Table 2).

Table 1 Irritant effect of different soaps on individuals with sensitive skin

Brand name	Erythema	Scaling	Fissures	IrIn
Aderma (dermopan)	0.600*	0.600*	0.266*	1.466**
Avecyde (liquid)	1.800	0.800	0.733	3.333
Avéne	1.200	0.933	0.466	2.599
Cetaphil	0.460	0.933	0.000	1.393
Dove white	0.200	0.000	0.000	0.200
Dove baby	0.533	0.600	0.000	1.133
Dove (liquid))	0.666	0.600	0.133	1.399
Dove pink	0.666	0.666	0.133	1.465
Johnson's baby	1.666	1.400	0.133	3.199
Johnson's baby/oat	1.333	1.400	0.066	2.799
Lux with glycerin	1.533	1.466	0.266	3.265
Nivea baby creamy	1.800	1.466	0.200	3.466
Nivea bath care	1.666	1.400	0.266	3.332
Nivea bath care, almond	1.533	1.400	0.066	2.999
Nivea bath care, oat	1.400	1.333	0.400	3.133
Oilatum	2.428	1.714	0.428	4.570
Natural oilatum	2.000	2.000	0.142	4.142
Zest neutral	2.140	1.785	0.290	4.215
Zest citrus sport	1.714	1.857	0.000	3.571
Zest herbal	1.857	1.428	0.428	3.713
Zest aqua	2.428	1.857	0.714	4.999
Palmolive green	1.857	1.428	0.428	3.713
Palmolive (white)	2.428	1.000	0.571	3.999
Palmolive botanicals	2.428	1.142	0.571	4.141
Palmolive botanicals with chamomile	2.714	0.714	0.000	3.428
Camay classic	1.857	1.000	0.430	3.287
Camay gala	3.142	1.285	0.857	5.284
Camay soft	3.142	1.142	1.142	5.426
Rosa venus	2.428	0.857	0.285	3.570

Soap emulsions or liquid cleansers were applied to the skin of forearm of 30 individuals as stated in Materials and Methods. Then, the presence of erythema, scaling and fissures was recorded and the irritation index (IrIn) determined.
*Arithmetic mean of the values of each parameter of skin irritation; **Sum of the values of skin irritation (IrIn).

pH

Only one of the products tested (Dove Baby™) had a neutral pH. Four soaps had a pH near 7.0, and another had a very acidic pH 3.61 (Avecyde™), whereas the remainder had high pH 9.85–12.35 (Table 2).

Correlation between pH and irritation effect

On the basis of our results, the soaps tested were grouped into three categories: (1) soaps with a low IrIn and pH near the neutral zone; (2) soaps with a high IrIn (> 3.571) and high pH (from 9.5 to 10.65); and products with the highest pH (> 11) and IrIn (from 2.79 to 3.466) (Fig. 1). The correlation between these two parameters was statistically significant ($P < 0.006$)

Hyperpigmentation

Almost all the products studied induced hyperpigmentation. Although we did not perform a statistical analysis of these data, it was evident that the degree of hyperpigmentation was related to the level of inflammation induced by the different products (post-inflammatory hyperpigmentation, data not shown).

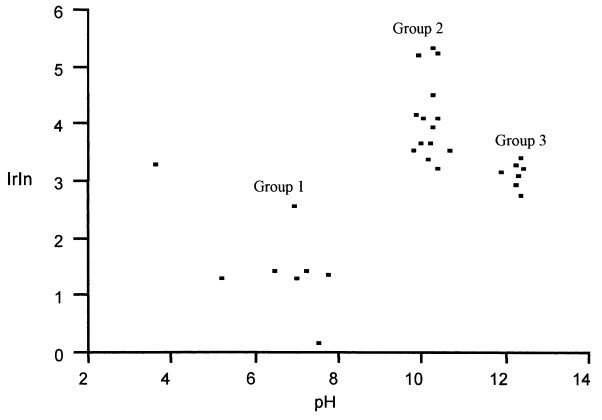

Figure 1 Correlation between pH and irritation index (IrIn). We identified three groups of soaps: low IrIn and pH near neutral zone; high pH and high IrIn; and highest pH and moderate IrIn

Table 2 Irritation index, pH and composition of tested cleansers

Brand name	Irritation*	pH	Composition
Aderm	1.466	6.44	Syndet
Avecyde	3.333	3.61	Syndet
Avéne	2.599	6.94	Syndet
Cetaphil	1.393	7.72	Syndet
Dove white	0.200	7.53	Syndet
Dove baby	1.133	7.0	Syndet
Dove (liquid)	1.399	5.16	Syndet
Dove pink	1.465	7.23	Syndet
Johnson's baby	3.199	11.9	Soap
Johnson's baby oat	2.799	12.35	Soap
Lux with glycerin	3.265	12.38	Soap
Nivea baby creamy	3.466	12.35	Syndet**
Nivea bath care	3.332	12.21	Syndet**
Nivea bath c. Almond	2.999	12.22	Syndet**
Nivea bath c. Oat	3.133	12.30	Syndet**
Oilatum	4.570	10.26	Syndet**
Natural oilatum	4.142	10.01	Syndet**
Zest neutral	4.215	9.85	Soap
Zest citrus sport	3.571	9.75	Soap
Zest herbal	3.713	9.97	Soap
Zest aqua	4.999	9.89	Soap
Palmolive green	3.713	10.18	Soap
Palmolive (white)	3.999	10.23	Soap
Palmolive botanicals	4.141	10.38	Soap
Palmolive botanicals/camomile	3.428	10.13	Soap
Camay classic	3.287	10.38	Soap
Camay gala	5.284	10.36	Soap
Camay soft	5.426	10.26	Soap
Rosa venus	3.570	10.65	Soap

The pH of each emulsion or liquid cleanser was recorded by using the Chemcadet pH meter (Cole-Parmer Instrument Co.).
*Irritation index, **plus mineral oil

Discussion

Most soaps and cleansers usually remove dirt adequately, but their use is not devoid of adverse side-effects. These adverse effects include damage to the barrier function of the skin, increased susceptibility to environmental irritants and antigens, skin irritation with erythema and edema, and reduction of the cosmetic qualities of the skin, such as moisture and smoothness. These changes are usually subtle, occurring slowly over time, and are more important in elderly and atopic patients.[20,21] Often, the association of these problems with the use of a particular type of soap is overlooked.[22] Skin dryness can be exacerbated by dry climate and the influence of hard water, which increases the irritant effect of soaps or detergents.[6]

Although it is important that dermatologists and the general population are aware of the irritation potential of products used for body cleansing, this information is not usually available; therefore, we decided to analyze the irritation effect of brand name products rather than isolated substances.

The chamber test used for assessing the irritant effects of soaps deliberately magnifies the conditions of exposure in order to enhance the effect of different products. The purpose of the chamber test is to achieve maximum effect of each compound, providing greater sensitivity and discriminating power, thus emphasizing the differences between soaps as much as possible.[19,23] In this regard, it is very likely that the "use test" or the repeated open test do not have the discriminating power that we were looking for in this study.

Cumulative irritant dermatitis is the most common type of irritant contact dermatitis, and develops as a result of a series of repeated and damaging insults to the skin hampering the adequate recovery of this tissue.[24–26] The repetitive irritation test with Finn chambers employed in this study allowed us to induce this syndrome.[27]

In this study we found that a group of five soap bars and one liquid skin cleanser (White Dove™, Dove Baby™, Cetaphil™ (bar), Dove liquid cleanser for hands™, Dove pink™ and Aderma™), have a low irritant effect. Only one of these soaps had a neutral pH, being the second less irritant to sensitive skin (Dove Baby™). It is important to recognize that Dove™, Cetaphil and Aderma™, which have a lower IrIn, are considered as synthetic detergents.[13] Commonly used soaps by the general population are soap based (Table 3).

As the soaps more frequently used by the general population showed a high irritation index (3.285–5.4) they should not be recommended for individuals with sensitive skin.

We found a significant correlation between pH and skin irritation ($P < 0.006$). However, the group of soap bars with the highest pH (> 11) only had a moderate IrIn. We do not have a suitable explanation for this phenomenon, but it is feasible that those products with a very high pH have a down-regulatory effect on the release of endogenous factors involved in skin inflammation.

It has been reported in the past that the prolonged disturbance of the skin acid mantle is not sufficient to induce clinical irritation.[28] Recently, it has been found that normal use of an alkaline soap bar causes a small increase in pH, perceived by subjects studied to be more irritating than a syndet.[29] In addition, the application of sodium lauryl sulfate under occlusion with a solution with high pH causes a low but significant increase in transepidermal water loss.[30] Therefore, we think that the alteration of skin pH produced by toilet soaps is an important factor to induce irritation in sensitive skin, contributing to eczema production in these patients. It is important to recall that the cumulative skin irritation in older adults requires prolonged recovery time, and that repeated exposure to harsh soaps could hinder appropriate skin repair.[31]

The dissociation constant (pKa) of a substance is another factor that contributes to the irritation potential of a substance, and a high value of this parameter seems to be predictive for

skin irritation.[32] However, all the soaps and cleansers tested in this study were comprised of a complex mixture of substances, and therefore we could not determine their pKa.

The prices of the products tested ranged from $0.0028 to $0.14 US dollars per gram. Interestingly there was no significant correlation between the price of the products and their irritation potential. In fact, the lowest IrIn was achieved by a soap with a price of 0.0082 US dollars per gram. Therefore, it is necessary that dermatologists point out that a highly price soap is not necessarily the best option for individuals with sensitive skin.

In addition, our results further indicate that good soaps are not characterized by their fragrance or appearance, nor by the place in which they are sold. Physicians, dermatologists included, should have accurate information about soaps and cleansers marketed for dry skin.

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Attachment 3 – Process sand hazard classification

Hazardous Waste Classification Worksheet (Revised 31st August 2004)

Box No.	Information Required	Information	
	Company Details		
A	**Company Name**	RUSAL AUGHINISH ALUMINA	
	Company Address	AUGHINISH ISLAND ASKEATON Co. LIMERICK	
	Date	30-3-2017	
	IPC or Waste License Number (if applicable)	P0035-05	
	Contact Person	LIAM FLEMING	
	Waste Description	BAUXITE RESIDUE = PROCESS SAND	
	European Waste Catalogue/Hazardous Waste List		
B	**Possible EWC Codes**	01 03 09	Asterisk Yes / No ☐ / ☑
		01 03 07 *	☑ / ☐
		— — — — — —	☐ / ☐
		— — — — — —	☐ / ☐
		— — — — — —	☐ / ☐
		— — — — — —	☐ / ☐
C	**Six-Digit EWC Code**	01-03-07 *	Asterisk Yes / No ☑ / ☐
D	**EWC Description**	OTHER WASTES CONTAINING DANGEROUS SUBSTANCES FROM PHYSICAL AND CHEMICAL PROCESSING OF METALLIFEROUS MINERALS.	
C1	***Mirror Entry Code (if applicable)***	01-03-09	Asterisk Yes / No ☐ / ☑
D1	***Mirror Entry Description (if applicable)***	RED MUD FROM ALUMINA PRODUCTION OTHER THAN THE WASTES MENTIONED IN 01-03-07*	
E	**Is this waste classified as hazardous waste according to HWL?**	Mirror Entry	☑
		No	☐
		Yes	☐

Hazardous Waste Classification Worksheet (Revised 31st August 2004)

Category I Waste (Box F)	
[] 1.	Anatomical substances, hospital or other clinical waste.
[] 2.	Pharmaceutical, medicinal or veterinary compounds.
[] 3.	Wood preservatives.
[] 4.	Biocides or phyto-pharmaceutical substances.
[] 5.	Residue from substances employed as solvents.
[] 6.	Halogenated organic substances not employed as solvents, excluding inert polymerized materials.
[] 7.	Tempering salts containing cyanides.
[] 8.	Mineral oils or oily substances (including cutting sludges).
[] 9.	Mixtures or emulsions of oil and water or hydrocarbon and water.
[] 10.	Substances containing polychlorinated biphenyls or polychlorinated terphenyls (including dielectrics).
[] 11.	Tarry materials arising from refining, distillation or any pyrolytic treatment (including still bottoms).
[] 12.	Inks, dyes, pigments, paints, lacquers or varnishes.
[] 13.	Resins, latex, plasticizers, glues or adhesives.
[] 14.	Chemical substances arising from research and development or teaching activities (including laboratory residues) which are not identified or are new and whose effects on humans or the environment are not known.
[] 15.	Pyrotechnics or other explosive materials.
[] 16.	Photographic chemicals or processing materials.
[] 17.	Any material contaminated with any congener of polychlorinated dibenzo-furan.
[] 18.	Any material contaminated with any congener of polychlorinated dibenzo-p-dioxin.

Category II Waste (Box G)	
[] 19.	Animal or vegetable soaps, fats or waxes.
[] 20.	Non-halogenated organic substances not employed as solvents.
[] 21.	Inorganic substances without metals or metal compounds.
[] 22.	Ashes or cinders.
[] 23.	Soil, sand or clay (including dredging spoils).
[] 24.	Non-cyanidic tempering salts.
[] 25.	Metallic dust or powder.
[] 26.	Spent catalyst materials.
[✓] 27.	Liquids or sludges containing metals or metal compounds.
[] 28.	Residue (other than scrubber sludges, sludges from water purification plants and sewage sludges (untreated or unsuitable for use in agriculture)) from pollution control operations (including baghouse dusts).
[] 29.	Scrubber sludges.
[] 30.	Sludges from water purification plants.
[] 31.	Decarbonization residue.
[] 32.	Ion-exchange column residue.
[] 33.	Sewage sludges, untreated or unsuitable for use in agriculture.
[] 34.	Residue from cleaning of tanks or equipment.
[] 35.	Contaminated equipment.
[] 36.	Contaminated containers (including packaging and gas cylinders).
[] 37.	Batteries or other electrical cells.
[] 38.	Vegetable oils.
[] 39.	Materials resulting from the selective collection of waste from households.
[] 40.	Any other waste.

Category II Constituents (Box H)	
[ ] 41.	Beryllium or beryllium compounds.
[ ] 42.	Vanadium compounds.
[ ] 43.	Chromium (VI) compounds.
[ ] 44.	Cobalt compounds.
[ ] 45.	Nickel compounds.
[ ] 46.	Copper compounds.
[ ] 47.	Zinc compounds.
[ ] 48.	Arsenic or arsenic compounds.
[ ] 49.	Selenium or selenium compounds.
[ ] 50.	Silver compounds.
[ ] 51.	Cadmium or cadmium compounds.
[ ] 52.	Tin compounds.
[ ] 53.	Antimony or antimony compounds.
[ ] 54.	Tellurium or tellurium compounds.
[ ] 55.	Barium compounds, excluding barium sulphate.
[ ] 56.	Mercury or mercury compounds.
[ ] 57.	Thallium or thallium compounds.
[ ] 58.	Lead or lead compounds.
[ ] 59.	Inorganic sulphides.
[ ] 60.	Inorganic fluorine compounds, excluding calcium fluoride.
[ ] 61.	Inorganic cyanides.
[ ] 62.	Any of the following alkaline or alkaline earth metals, namely, lithium, sodium, potassium, calcium, magnesium in uncombined form.
[ ] 63.	Acidic solutions or acids in solid form.
[✓] 64.	Basic solutions or bases in solid form.
[ ] 65.	Asbestos (dust or fibres).
[ ] 66.	Phosphorus: phosphorus compounds, excluding mineral phosphates.
[ ] 67.	Metal carbonyls.
[ ] 68.	Peroxides.
[ ] 69.	Chlorates.
[ ] 70.	Perchlorates.
[ ] 71.	Azides.
[ ] 72.	Polychlorinated biphenyls or polychlorinated terphenyls.
[ ] 73.	Pharmaceutical or veterinary compounds.
[ ] 74.	Biocides or phyto-pharmaceutical substances (including pesticides).
[ ] 75.	Infectious substances.
[ ] 76.	Creosotes.
[ ] 77.	Isocyanates or thiocyanates.
[ ] 78.	Organic cyanides (including nitriles).
[ ] 79.	Phenols or phenol compounds.
[ ] 80.	Halogenated solvents.
[ ] 81.	Organic solvents, excluding halogenated solvents.
[ ] 82.	Organohalogen compounds, excluding inert polymerized materials and other substances referred to in this Part.
[ ] 83.	Aromatic compounds; polycyclic and heterocyclic organic compounds.
[ ] 84.	Aliphatic amines.
[ ] 85.	Aromatic amines.
[ ] 86.	Ethers.
[ ] 87.	Substances of an explosive character, excluding those referred to elsewhere in this Part.
[ ] 88.	Sulphur organic compounds.
[ ] 89.	Any congener of polychlorinated dibenzo-furan.
[ ] 90.	Any congener of polychlorinated dibenzo-p-dioxin.
[ ] 91.	Hydrocarbons and their oxygen, nitrogen or sulphur compounds not otherwise referred to in this Part.

Box I: Property Test Results and Waste Classification					
Property	**Property Testing**			**Waste Classification**	
	Test Code	**Title of Test**	**Results**	**Hazard (s)**	**Risk Phrase (s)**
Explosive					
Oxidising					
Flammable					
Irritant/ Corrosive					
Harmful/Toxic					
Carcinogenic					
Infectious	No test methods available for this property				
Toxic for Reproduction					
Mutagenic					
Ecotoxic					
Residuary hazardous property					

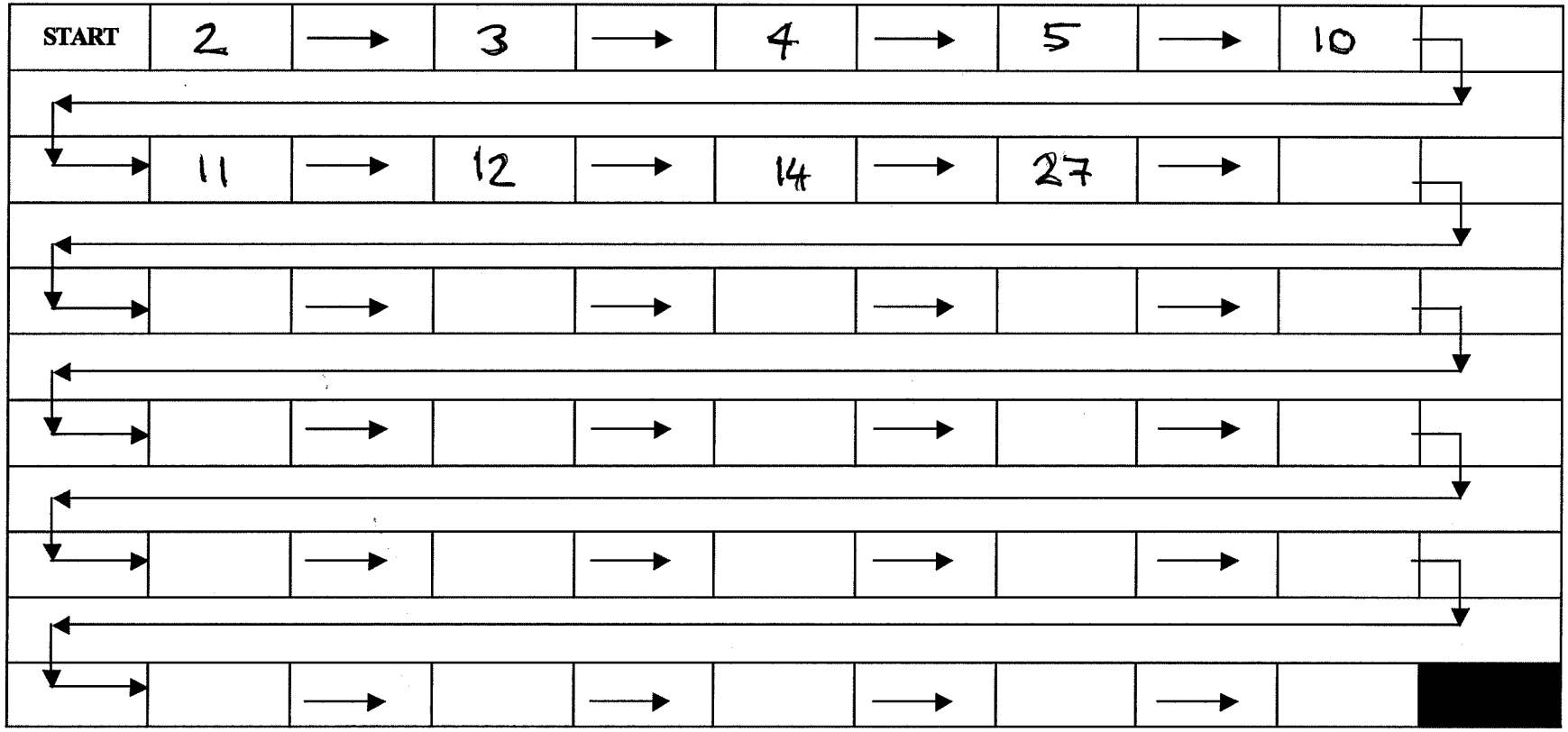
Sand

Mineral Form	Chemical Fomula	% wt/wt as is	CAS No	R Phrase	Reference	Carcinogen group	Toxic for reproduction	Mutagenic category
Goethite	Fe2O3.H2O	29.8	1310-14-1	Not classified	ESIS & Sigma Aldrich SDS	-	-	-
Hematite	Fe2O3	24.4	1317-60-8	Not classified	ESIS & Minelco SDS	-	-	-
Boehmite	Al2O3.H2O	8.8	1318-23-6	Not classified	ESIS & Nabaltec SDS	-	-	-
Sodalite	3(Na2O.Al2O3.2SiO2.2H2O)0.8Na2CO3.0.2Na2SO4	3.9	1344-00-9	R36/37/38	ESIS & Sigma Aldrich SDS	-	-	-
Hydrogarnet	3CaO.Al2O3.SiO2.4H2O	3.7	68131-74--8	Not classified	Rocktron SDS	-	-	-
Diaspore solid solution goethite	Al2O3.H2O	2.8	1318-23-6	Not classified	As per boehmite	-	-	-
Perovskite	CaTiO3	2.1	12049-50-2	Not classified	Sigma Aldrich SDS	-	-	-
Rutile	TiO2	1.2	13463-67-7	R36/37/38	ESIS & Sigma Aldrich SDS	-	-	-
Quartz	SiO2	1.0	14808-60-7	R48/20, R40/20	ESIS & U.S. Silica Co. SDS	3	-	3
Carbonate Apatite	5.2CaO.0.8Na2O.2.5CO2.P2O5	1.0	471-34-1	R36	Sciencelab SDS (CaCO3)	-	-	-
Sodium Hydroxide	NaOH	0.3	1310-73-2	R35	ESIS & Sigma Aldrich SDS	-	-	-
Sodium Carbonate	Na2CO3	0.2	497-19-8	R36/37/38	ESIS & Sigma Aldrich SDS	-	-	-
Zirconium silicate	ZrSiO4	0.1	10101-52-7	R20, R36/37/38	ESIS & Chemical Book SDS	-	-	-
Water	H2O	20.0				-	-	-

Box K : Waste Composition Details		
Properties with thresholds (Box K1)		
Property	**Threshold (% w/w)**	**Total (% w/w) in Waste**
Flash Point ≤ 55°C		0
Very Toxic	≥ 0.1	0
Toxic	≥ 3	0
Harmful	≥ 25	1.1 %
Corrosive with Risk Phrase R35	≥ 1	0.3 %
Corrosive with Risk Phrase R34	≥ 5	0
Irritant with Risk Phrase R41	≥ 10	0
Irritant with Risk Phrases R36, R37, R38	≥ 20	6.4 %
Carcinogen Category 1 or 2	≥ 0.1	0
Carcinogen Category 3	≥ 1	1.0 %
Toxic for Reproduction Category 1 and 2 with Risk Phrases R60, R61	≥ 0.5	0
Toxic for Reproduction Category 3 with Risk Phrases R62, R63	≥ 5	0
Mutagenic Category 1 and 2 with Risk Phrase R46	≥ 0.1	0
Mutagenic Category 3 with Risk Phrase R40	≥ 1	1.0 %
Properties without thresholds (Box K2)		
Property		**Total (% w/w) in Waste**
Explosive		0
Oxidising		0
Infectious		0
Ecotoxic		0
Residuary hazardous property		0

Final EWC Code		
L	Final EWC Code	0 1 0 3 0 9
M	Final EWC Description	RED MUD FROM ALUMINA PRODUCTION OTHER THAN WASTES IN 01-03-07 *

Box N - Route Map - Insert the tab numbers as you are directed to them (not applicable to computer tool)



Attachment 4 – Salt cake hazard classification

Hazardous Waste Classification Worksheet (Revised 31st August 2004)

Box No.	Information Required	Information	
		Company Details	
A	**Company Name**	RUSAL AUGHINISH ALUMINA	
	Company Address	AUGHINISH ISLAND ASKEATON CO. LIMERICK	
	Date	30-3-2013	
	IPC or Waste License Number (if applicable)	P0035-05	
	Contact Person	LIAM FLEMING	
	Waste Description	SALT CAKE	
		European Waste Catalogue/Hazardous Waste List	
B	**Possible EWC Codes**	01 03 07 *	Asterisk Yes / No ☑ / ☐ ☐ / ☐ ☐ / ☐ ☐ / ☐ ☐ / ☐ ☐ / ☐
C	**Six-Digit EWC Code**	01-03-07 *	Asterisk Yes / No ☑ / ☐
D	**EWC Description**	OTHER WASTES CONTAINING DANGEROUS SUBSTANCES FROM PHYSICAL AND CHEMICAL PROCESSING	
C1	***Mirror Entry Code (if applicable)***		Asterisk Yes / No ☐ / ☐
D1	***Mirror Entry Description (if applicable)***		
E	**Is this waste classified as hazardous waste according to HWL?**	Mirror Entry No Yes	☐ ☐ ☑

Hazardous Waste Classification Worksheet (Revised 31st August 2004)

Category I Waste (Box F)	
[] 1.	Anatomical substances, hospital or other clinical waste.
[] 2.	Pharmaceutical, medic inal or veterinary compounds.
[] 3.	Wood preservatives.
[] 4.	Biocides or phyto-pharmaceutical substances.
[] 5.	Residue from substances employed as solvents.
[] 6.	Halogenated organic substances not employed as solvents, excluding inert polymerized materials.
[] 7.	Tempering salts containing cyanides.
[] 8.	Mineral oils or oily substances (including cutting sludges).
[] 9.	Mixtures or emulsions of oil and water or hydrocarbon and water.
[] 10.	Substances containing polychlorinated biphenyls or polychlorinated terphenyls (including dielectrics).
[] 11.	Tarry materials arising from refining, distillation or any pyrolytic treatment (including still bottoms).
[] 12.	Inks, dyes, pigments, paints, lacquers or varnishes.
[] 13.	Resins, latex, plasticizers, glues or adhesives.
[] 14.	Chemical substances arising from research and development or teaching activities (including laboratory residues) which are not identified or are new and whose effects on humans or the environment are not known.
[] 15.	Pyrotechnics or other explosive materials.
[] 16.	Photographic chemicals or processing materials.
[] 17.	Any materia l contaminated with any congener of polychlorinated dibenzo-furan.
[] 18.	Any material contaminated with any congener of polychlorinated dibenzo-p-dioxin.

Category II Waste (Box G)	
[] 19.	Animal or vegetable soaps, fats or waxes.
[] 20.	Non-halogenated organic substances not employed as solvents.
[] 21.	Inorganic substances without metals or metal compounds.
[] 22.	Ashes or cinders.
[] 23.	Soil, sand or clay (including dredging spoils).
[] 24.	Non-cyanidic tempering salts.
[] 25.	Metallic dust or powder.
[] 26.	Spent catalyst materials.
[✓] 27.	Liquids or sludges containing metals or metal compounds.
[] 28.	Residue (other than scrubber sludges, sludges from water purification plants and sewage sludges (untreated or unsuitable for use in agriculture)) from pollution control operations (including baghouse dusts).
[] 29.	Scrubber sludges.
[] 30.	Sludges from water purification plants.
[] 31.	Decarbonization residue.
[] 32.	Ion-exchange column residue.
[] 33.	Sewage sludges, untreated or unsuitable for use in agriculture.
[] 34.	Residue from cleaning of tanks or equipment.
[] 35.	Contaminated equipment.
[] 36.	Contaminated containers (including packaging and gas cylinders).
[] 37.	Batteries or other electrical cells.
[] 38.	Vegetable oils.
[] 39.	Materials resulting from the selective collection of waste from households.
[] 40.	Any other waste.

Category II Constituents (Box H)

- [ ] 41. Beryllium or beryllium compounds.
- [ ] 42. Vanadium compounds.
- [ ] 43. Chromium (VI) compounds.
- [ ] 44. Cobalt compounds.
- [ ] 45. Nickel compounds.
- [ ] 46. Copper compounds.
- [ ] 47. Zinc compounds.
- [ ] 48. Arsenic or arsenic compounds.
- [ ] 49. Selenium or selenium compounds.
- [ ] 50. Silver compounds.
- [ ] 51. Cadmium or cadmium compounds.
- [ ] 52. Tin compounds.
- [ ] 53. Antimony or antimony compounds.
- [ ] 54. Tellurium or tellurium compounds.
- [ ] 55. Barium compounds, excluding barium sulphate.
- [ ] 56. Mercury or mercury compounds.
- [ ] 57. Thallium or thallium compounds.
- [ ] 58. Lead or lead compounds.
- [ ] 59. Inorganic sulphides.
- [ ] 60. Inorganic fluorine compounds, excluding calcium fluoride.
- [ ] 61. Inorganic cyanides.
- [ ] 62. Any of the following alkaline or alkaline earth metals, namely, lithium, sodium, potassium, calcium, magnesium in uncombined form.
- [ ] 63. Acidic solutions or acids in solid form.
- [x] 64. Basic solutions or bases in solid form.
- [ ] 65. Asbestos (dust or fibres).
- [ ] 66. Phosphorus: phosphorus compounds, excluding mineral phosphates.
- [ ] 67. Metal carbonyls.
- [ ] 68. Peroxides.
- [ ] 69. Chlorates.
- [ ] 70. Perchlorates.
- [ ] 71. Azides.
- [ ] 72. Polychlorinated biphenyls or polychlorinated terphenyls.
- [ ] 73. Pharmaceutical or veterinary compounds.
- [ ] 74. Biocides or phyto-pharmaceutical substances (including pesticides).
- [ ] 75. Infectious substances.
- [ ] 76. Creosotes.
- [ ] 77. Isocyanates or thiocyanates.
- [ ] 78. Organic cyanides (including nitriles).
- [ ] 79. Phenols or phenol compounds.
- [ ] 80. Halogenated solvents.
- [ ] 81. Organic solvents, excluding halogenated solvents.
- [ ] 82. Organohalogen compounds, excluding inert polymerized materials and other substances referred to in this Part.
- [ ] 83. Aromatic compounds; polycyclic and heterocyclic organic compounds.
- [ ] 84. Aliphatic amines.
- [ ] 85. Aromatic amines.
- [ ] 86. Ethers.
- [ ] 87. Substances of an explosive character, excluding those referred to elsewhere in this Part.
- [ ] 88. Sulphur organic compounds.
- [ ] 89. Any congener of polychlorinated dibenzo-furan.
- [ ] 90. Any congener of polychlorinated dibenzo-p-dioxin.
- [ ] 91. Hydrocarbons and their oxygen, nitrogen or sulphur compounds not otherwise referred to in this Part.

Box I: Property Test Results and Waste Classification					
Property	**Property Testing**			**Waste Classification**	
	Test Code	**Title of Test**	**Results**	**Hazard (s)**	**Risk Phrase (s)**
Explosive					
Oxidising					
Flammable					
Irritant/ Corrosive					
Harmful/Toxic					
Carcinogenic					
Infectious	No test methods available for this property				
Toxic for Reproduction					
Mutagenic					
Ecotoxic					
Residuary hazardous property					

Saltcake

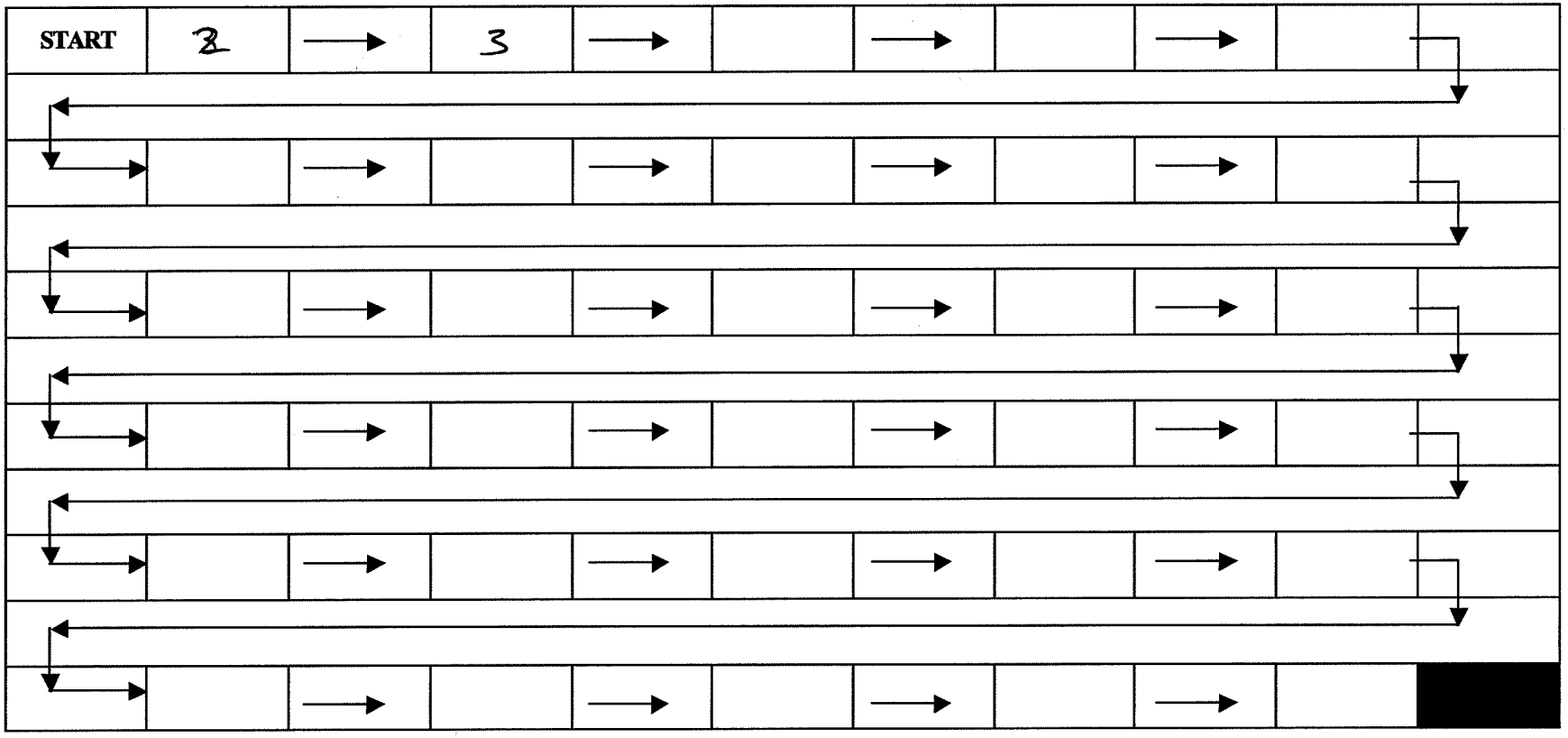
Mineral Form	Chemical Fomula	% wt/wt as is	CAS No	R Phrase	Carcinogen group	Toxic for reproduction	Mutagenic category
Sodium aluminate	NaAlO2	15.4	1302-42-7	R35	-	-	-
Sodium oxalate	Na2C2O4	15.3	62-76-0	R21/22, R38	-	-	-
Sodium hydroxide	NaOH	10.3	1310-73-2	R35	-	-	-
Sodium humates	Na-C	7.7	Not known	R36/37/38 (guess)	-	-	-
Sodium carbonate	Na2CO3	3.3	497-19-8	R36/37/38	-	-	-
Sodium sulphate	Na2SO4	0.2	7757-82-6	R36	-	-	-
Sodium vanadate	Na3VO4	0.1	13721-39-6	R23/24/25	-	-	-
Water		44.0			-	-	-

Hazardous Waste Classification Worksheet (Revised 31st August 2004)

Box K : Waste Composition Details		
Properties with thresholds (Box K1)		
Property	**Threshold (% w/w)**	**Total (% w/w) in Waste**
Flash Point ≤ 55°C		0
Very Toxic	≥ 0.1	0
Toxic	≥ 3	0·1 %
Harmful	≥ 25	15.3%
Corrosive with Risk Phrase R35	≥ 1	25·7 %
Corrosive with Risk Phrase R34	≥ 5	0
Irritant with Risk Phrase R41	≥ 10	0
Irritant with Risk Phrases R36, R37, R38	≥ 20	26·5 %
Carcinogen Category 1 or 2	≥ 0.1	0
Carcinogen Category 3	≥ 1	0
Toxic for Reproduction Category 1 and 2 with Risk Phrases R60, R61	≥ 0.5	0
Toxic for Reproduction Category 3 with Risk Phrases R62, R63	≥ 5	0
Mutagenic Category 1 and 2 with Risk Phrase R46	≥ 0.1	0
Mutagenic Category 3 with Risk Phrase R40	≥ 1	0
Properties without thresholds (Box K2)		
Property		**Total (% w/w) in Waste**
Explosive		0
Oxidising		0
Infectious		0
Ecotoxic		0
Residuary hazardous property		0

Final EWC Code		
L	Final EWC Code	0 1 0 3 0 7 *
M	Final EWC Description	OTHER WASTES CONTAINING DANGEROUS SUBSTANCES FROM PHYSICAL & CHEMICAL PROCESSING OF METALLIFEROUS MINERALS.

Box N - Route Map - Insert the tab numbers as you are directed to them (not applicable to computer tool)



Appendix 4

RUSAL
AUGHINISH

Classification of Farmed Bauxite Residue (01 03 09) as Non Hazardous at Rusal Aughinish Alumina Limited

Date: September 2015

RUSAL
AUGHINISH

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Glossary

Abbreviations/Symbols	
RAAL	Rusal Aughinish Alumina Ltd.
BRDA	Bauxite residue disposal area
ECHA	European Chemicals Agency
EU	European Union
ha	Hectare
Mt/yr	Million tonnes per year
IEL	Industrial Emissions License
HP	Hazardous Property
EWC	European Waste Catalogue
EPA	Environmental Protection Agency
CLP	Chemicals, Labelling and Packaging

1. Executive Summary

Rusal Aughinish Alumina Limited (RAAL) is the largest Alumina refinery in Europe with an annual production capacity of 1.95mt/yr of alumina *via* the Bayer process. The major waste stream of the Bayer process is bauxite residue. Bauxite residue undergoes numerous stages of washing and filtration prior to discharge to the Bauxite Residue Disposal Area (BRDA). At RAAL a process of enhanced atmospheric carbonation termed "bauxite residue farming" has been developed to minimise the pH of deposited bauxite residue to the BRDA. Bauxite Residue farming reduces the residue pH below 11.5.

Farmed bauxite residue is the terminology applied by RAAL to describe bauxite residue which has undergone a process of partial neutralisation. Within the Alumina Industry bauxite residue may also be termed red mud.

This report summarises an assessment of RAAL farmed bauxite residue which employs the current EU legislation as specified by the EU Waste Framework Directive (2008/98/EC), the Hazardous Waste Directive (2000/532/EC) and the Extractive Waste Directive (2006/21/EC).

Summation of the Hazard statement codes for each compound present in farmed bauxite residue shows no threshold is exceeded for any of the hazard properties (HP). **Therefore, farmed bauxite residue is non-hazardous.**

The non-hazardous waste code '01 03 09 red mud from alumina production other than the wastes mentioned in 01 03 10', is assigned to RAAL farmed bauxite residue under 2014/955/EU Updated List of wastes.

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2. Site Description

The RAAL refinery is located on Aughinish Island, on the southern shore of the Shannon Estuary 33 kilometres west of Limerick city between the towns of Askeaton and Foynes. The plant commenced operation in 1983 and today has a production capability of 1.95mt/yr alumina. It sources bauxite from Guinea, Brazil and Guyana.

3. Storage Area Design

The bauxite residue is deposited in an engineered facility called the Bauxite Residue Disposal Area that has been designed to ensure the long-term stability of the residue. The BRDA is formed by construction of perimeter embankments: an inner and outer embankment with a perimeter intercept channel in between. The bauxite residue is retained by a perimeter stack wall constructed of rockfill, which is raised consecutively in 2 metre vertical stages (upstream embankment raising). There is also a flood tidal defence berm between the BRDA and the Shannon Estuary foreshore that protects the BRDA from wave and tidal erosion.

The bedrock of the island area is Carboniferous Limestone. There are outcrops of this limestone on the northern and eastern area of the Aughinish Island. A discontinuous layer of glacial till is also present. The estuarine sediments are on average 8 metres thick particularly adjacent to the estuary where the BRDA is located.

The BRDA is constructed with engineered composite liners on the underlying strata. All perimeter intercept channels are also lined with this engineered composite liner.

The BRDA has been designed and is operated to ensure that all water run-off from the facility is collected and treated before discharge, and that any subsurface seepage from beneath the facility is prevented. The water management system provides for collection and treatment of surface water runoff and leachate from the BRDA.

4. Bauxite Residue Disposal Area Operation

The deposition method employed at RAAL is dry stacking of washed, filtered residue which is pumped by positive displacement pumps to the BRDA at 58% solids, where the bauxite residue is layered at a slope of approximately 2.5%, then subsequently farmed to increase the percent solids to 74%. The combined BRDA area is effectively a large mono-cell and is divided into 46 operational areas or cells to facilitate short deposition times and thin layer deposition.

Partial neutralisation of the bauxite residue by atmospheric carbonation through farming produces a residue with pH below 11.5 which is suitable for remediation and revegetation [1]. This post deposition atmospheric carbonation *via* farming process is outlined below.

4.1 Amphirolling

Bauxite residue at RAAL undergoes 3 stages of counter current washing in large settling vessels. The residue is then filtered on 8 large drum filters where it undergoes a final stage of washing with hot clean condensate. After vacuum filtration the residue is diluted with water, sheared and thinned in an agitated tank and then pumped as a 58% solids paste to the BRDA. In this state the deposited bauxite residue cannot yet be traversed by conventional machinery and first must be dewatered and compacted. An amphibious vehicle called an amphirol is employed to carry out this de-watering and compaction.

The amphirol travels using scrolls which act as semi-flotation devices to allow the vehicle to move through the residue. As the amphirol travels it compresses the residue and creates tracks or furrows. These furrows allow the water which has been “squeezed” from the residue to drain along the sloping stack towards the perimeter wall of the cell and into the perimeter channel. Amphirolling for compaction can require up to 20 travel times.

Figure 1: Bauxite residue farming and atmospheric carbonation process at RAAL

4.2 Grading

Once the residue has compacted to >70% solids by multiple passes of the amphirol, the residue surface is then graded by a bulldozer to level the surface and generate a constant gradient from the discharge (high point) to the perimeter wall (low point). This makes the residue suitable for conventional agricultural machinery to travel and operate on its surface. In this condition the dewatered residue is also capable of being broken into small lumps to allow for exposure to CO_2 in the air. The grading also establishes the base for the subsequent residue layer to be deposited.

4.3 Ripping

Once the residue surface has been re-graded the compacted residue layer must be "ripped" to open the 'compacted residue' and allow it to be easily worked by the other machinery used in the carbonation process. A tractor subsoiler attachment is used to rip and break the compacted residue layer into large lumps. The subsoiler has a working depth of 40-45cm.

4.4 Ploughing and Harrowing

The 'ripped' residue lumps must then be broken into smaller lumps and aerated a number of times to carbonate and neutralise any residual caustic. This is achieved by an efficient harrowing unit called a 'spader'. Once the subsoiler has loosened the bauxite residue layer, a tractor-driven 'spader' digs into and harrows the broken up residue lumps. Approximately 10-16 passes of the spader at up to 2 passes per day bring about sufficient exposure and carbonation to reduce bauxite residue pH below 11.5. The harrowing process using a spader can normally be conducted in a period of 1-2 weeks.

4.5 Final Compaction

While a bauxite residue layer is being harrowed a lot of voidage is created within the active layer. This is the mechanism by which the residue is exposed to atmospheric CO_2.

Once carbonation is completed as evidenced by pH measurements of samples from the cell, the area is then re-graded using a bulldozer to remove any depressions. Finally the cell is re-compacted using a vibrating plate compactor or a vibratory roller to maximise in-situ compaction and prepare the cell for the subsequent layer of residue. Through amphirolling, harrowing and final re-compaction the initial 40 cm deep layer of residue is compacted into a 30 cm deep well-compacted and partially neutralised bauxite residue layer. The cell is then ready for the subsequent layer of residue.

5. EU Extractive Waste Classification Legislation

There is a legislative framework within the European Union (EU) that specifies precise criteria for classification of waste as hazardous or non-hazardous. Bauxite residue disposal and its classification are directly subject to the following legislation;

- Hazardous Waste legislation (2000/532/EC) and Revised Waste Framework Directive (2008/98/EC)
- Extractive Waste Directive (2006/21/EC)

Design, operation and the ultimate closure of the RAAL BRDA for farmed bauxite residue storage is licensed under the Extractive Waste Directive 2006/21/EC. The BRDA is classified as a Category A facility under the Extractive Waste Directive due to its scale and location adjacent to a Special Area of Conservation. This classification ensures that the design and operation provides the highest level of environmental protection possible. RAAL is required by its Industrial Emissions License (IEL P0035-06) to minimise the pH of deposited residue. To achieve this, a process of enhanced atmospheric carbonation termed 'Bauxite Residue Farming' has been developed.

In terms of waste classification the Extractive Waste Directive refers to the Hazardous Waste classification methodology and thus farmed bauxite residue hazard classification is addressed by Hazardous Waste legislation. Annex II of this Extractive Waste Directive states that…"*classification of the waste shall be according to the relevant entry in Directive 2000/532/EC with particular regard to its hazardous characteristics".*

Although the Chemicals, Labelling and Packaging (CLP) legislation is not directly applicable to waste (*ECHA Guidance on the Application of the CLP Criteria, 2015*) [2] there are moves to harmonise the Waste and CLP legislation. The CLP legislation also details the specific concentration limits for hazardous compounds and describes the tests required for direct Hazardous Property (HP) testing of the waste to directly determine if a waste exhibits a particular HP.

The methodology to classify a waste is as follows.

- Is the waste a 'Special Waste' subject to its own specific legislative provisions and therefore excluded from the scope of general Hazardous Waste legislation e.g. radioactive waste or decommissioned explosives.
  Note: While bauxite residue disposal is primarily legislated via the Extractive Waste Directive 2006/21/EC, its waste classification follows the Hazardous Waste legislation.

- Is the Waste already coded/classified in the EU 'List of Wastes'?
  Note: Regarding bauxite residue there are two possible codes, one being hazardous and the other being non-hazardous. Thus an assessment of each bauxite residue type

from each Alumina Refinery BRDA is required to determine which code on the official EU 'List of Wastes' should be applied to the bauxite residue in question.

- Determine the detailed composition of the waste mixture down to 0.1% concentration. *Note: It is necessary to identify the specific compounds present in the waste rather than employ elemental analysis.*

- Determine the contribution to Hazardous Property of each compound present in the waste

- For each compound present in the waste identify if it is classified as dangerous i.e. is there an associated Risk phrase and Hazardous Property (HP) associated with that compound.

- For each HP (there are 15 potential HPs in total) sum all of the % compositions of compounds that contribute to the HP in question.

- Determine if the summation of the % compositions contributing to any specific HP causes the waste to exceed the thresh-hold for that HP. If so the bauxite residue would then be classified as having that HP and must be classified as hazardous due to the HP in question unless direct HP testing confirms that the waste is not hazardous.

6. Farmed Bauxite Residue Classification

6.1 Farmed Bauxite Residue Analysis

Full compositional analysis is carried out quarterly on farmed bauxite residue at RAAL employing such techniques as X-Ray Fluorescence, Thermo Gravimetric Analysis, Differential Scanning Calorimetry, Ion Chromatography, Atomic Absorption Spectroscopy and Inductively Coupled Plasma.

The principal sources of information for Hazard statement codes were:

- Safety Data Sheets from Sigma Aldrich
- Safety Data sheets from other large companies in the absence of a Sigma Aldrich SDS.

Full Chemical Analysis				
Compound	**Formula**	**w/w%**	**Hazard Statement Code**	**CAS No.**
Moisture	Free H2O	21.9	*	
Aluminum Goethite	(Fe,Al)2O3.H2O	20.9	*	1310-14-1
Hematite	Fe2O3	18.75	*	1317-60-8
Calcium Cancrinite	3(Na2O.Al2O3.2SiO2)2CaCO3	12.15	*	12172-98-4
Bayer Sodalite	3(Na2O.Al2O3.2SiO2.2H2O)0.8Na2CO3 .0.2Na2SO4	5.35	*	1344-00-9
Gibbsite	Al2O3.3H2O	4.85	H319	21645-51-2
Perovskite	CaTiO3	4.1	*	12049-50-2
Anatase and Rutile	TiO2	4.1	H332, H319, H335, H315	1313-70-0/ 13463-67-7
Hydrogarnet	3CaO.Al2O3.SiO2.4H2O	2.95	*	68131-78-8
Boehmite	Al2O3.H2O	2.15	*	1318-23-6
Quartz	SiO2	0.7	H372, H373	14808-60-7
Sodium Carbonate	Na2CO3	0.31	H319	497-19-8
Zircon	ZrSiO4	0.3	H332, H319, H335, H315	10101-52-7
Carbonate Apatite	5.2CaO.0.8Na2O.2.5CO2.P2O5	0.2	H319	471-34-1
Gypsum	CaSO4.2H2O	0.15	*	10101-41-4
Sodium Sulphate	Na2SO4	0.075	*	7757-82-6
Sodium BiCarbonate	NaHCO3	0.045	H315, H319	144-55-8
Sodium Fluoride	NaF	0.02	H300 (cat 2), H315, H319	7681-49-4
Sodium Aluminate	NaAl(OH)4	0.005	H290, H314	11138-49-1
Sodium Hydroxide	NaOH	0	H314	1310-73-2
Trace Metals - Semi Quantitative XRF				
Chromium Trioxide	Cr2O3	0.2	*	1308-38-9
Vanadium Pentoxide	V2O5	0.2	H302, H332,H318, H341, H361, H335, H372, H411	1314-62-1
Magnesium Oxide	MgO	0.12	*	1309-48-4
Cerium Oxide	CeO	0.02	*	1306-38-3
Potassium Carbonate	K2CO3	0.03	H302, H335, H315, H319	584-08-7
Manganese Oxide	MnO	0.035	*	1344-43-0
Gallium Trioxide	Ga2O3	0.0085	*	12024-21-4
Arsenic Trioxide	As2O3	0.01	H300, H314, H350, H400, H410	1327-53-3
Niobium Pentoxide	Nb2O5	0.014	H315, H319, H335	1313-96-8
Zinc Oxide	ZnO	0.005	H410	1314-13-2
Lead oxide	PbO	0.007	H302, H332, H360Df, H373, H410	1317-36-8
Yttrium Trioxide	Y2O3	0.0095	H315, H335	1314-36-9
Strontium Oxide	SrO	0.0095	H314	1314-11-0
Copper Oxide	CuO	0.004	H400, H412	1317-38-0
Thorium Oxide	ThO	0.01	H301, H311, H331, H350, H373	1314-20-1

Table 1: Full Chemical Analysis

***No hazard statement code classified**

6.2 Waste Classification

In the case of farmed bauxite residue there are two possible waste codes which can be assigned under 2014/955/EU Updated List of wastes amending (2000/532/EC).

- 01 03 10* red mud from alumina production containing hazardous substances other than the wastes mentioned in 01 03 07 and
- 01 03 09 red mud from alumina production other than the wastes mentioned in 01 03 10

Where * denotes hazardous waste.

The classification of the waste is based on the application of the updated Annex to Waste Framework Directive (1357/2014) to the compositional analysis of the farmed bauxite residue under hazardous properties HP1-15. A waste classification tool has been developed and released by environmental protection Agency (EPA) Ireland based on the legislation and is the basis for classification of farmed bauxite residue [6]. The commission regulation 1357/2014 states that the "*attribution of the hazardous property HP 14 is made on the basis of the criteria laid down in Annex VI to Council Directive 67/548/EEC*." As such, the hazard property HP14 is assessed based on this criterion according to the waste classification tool released by EPA, Ireland.

Table 2 summarises the hazard statement codes in each of the hazard property category compared to the threshold for each category based on the typical farmed bauxite residue composition in Table 1 above. The Analysis of the compositional data shows that RAAL farmed bauxite residue does not exceed the concentration limits of any of the hazardous properties and is classified as non-hazardous.

Hazard Property	Hazard Class	Hazard Code	Threshold	Sample	Hazardous
HP1	Explosive	H200	Y/N	N	N
		H201	Y/N	N	N
		H202	Y/N	N	N
		H203	Y/N	N	N
		H204	Y/N	N	N
		H240	Y/N	N	N
		H241	Y/N	N	N
HP2	Oxidising	H270	Y/N	N	N
		H271	Y/N	N	N
		H272	Y/N	N	N
HP3	Flammable	H220	Y/N	N	N
		H221	Y/N	N	N
		H222	Y/N	N	N
		H223	Y/N	N	N
		H224	Y/N	N	N
		H225	Y/N	N	N
		H226	Y/N	N	N
		H228	Y/N	N	N
		H242	Y/N	N	N
		H250	Y/N	N	N
		H251	Y/N	N	N
		H252	Y/N	N	N
		H260	Y/N	N	N
		H261	Y/N	N	N
HP4	Irritant	H314	1	0	N
		H318	10	0	N
		H315 +H319	20	8.95	N
HP5	Specific target Organ Toxicity	H370	1	0	N
		H371	10	0	N
		H335	20	4.1	N
		H372	1	0.7	N
		H373	10	0.7	N
		H304	10	0	N
HP6	Acute Toxicity	H300 (cat 1)	0.1	0	N
		H300 (cat 2)	0.25	0	N
		H301	5	0	N
		H302	25	0	N
		H310	0.25	0	N
		H310	2.5	0	N
		H311	15	0	N
		H312	55	0	N

Hazard Property	Hazard Class	Hazard Code	Threshold	Sample	Hazardous
		H330	0.1	0	N
		H330	0.5	0	N
		H331	3.5	0	N
		H332	22.5	4.4	N
HP7	Carcinogenic	H350	0.1	0.02	N
		H351	1	0	N
HP8	Corrosive	H314	5	0	N
HP9	Infectious	**	Y/N	N	N
HP10	Toxic for Reproduction	H360	0.3	0.007	N
		H361	3	0.2	N
HP11	Mutagenic	H340	0.1	0	N
		H341	1	0.2	N
HP12	Release of Acute Toxic gas	UEH029	Y/N	N	N
		UEH031	Y/N	N	N
		UEH032	Y/N	N	N
HP13	Sensitising	H317	10	0	N
		H334	10	0	N
HP14	Ecotoxic	R50 and R51	1	0.08	N
		R50 and R53	25	0	N
		R52	25	0	N
		R53	25	0.2	N
HP15	Waste capable of exhibiting a hazardous property listed above not directly displayed by the original waste	H205	Y/N	N	N
		EUH001	Y/N	N	N
		EUH019	Y/N	N	N
		EUH044	Y/N	N	N

List of Wastes Entry	Hazardous Y/N	Description
01 03 09	N	Red mud from alumina production other than the wastes mentioned in 01 03 10 01

Table 2: Classification of RAAL Farmed bauxite residue

7. Conclusion

At RAAL bauxite residue is thoroughly washed and significantly dewatered prior to disposal in the licenced 'state of the art' BRDA. A process of enhanced atmospheric carbonation termed "bauxite residue farming" has been developed at RAAL to carbonate any residual caustic and minimise the pH of the deposited bauxite residue. This bauxite residue farming reduces the pH of farmed bauxite residue below 11.5. Bauxite residue farming also improves the compaction and dry density of the residue increasing storage efficiency.

This assessment of RAAL farmed bauxite residue applies the current EU legislation as specified by the EU Waste Framework Directive (2008/98/EC), the Hazardous Waste Directive (2000/532/EC) and the Extractive Waste Directive (2006/21/EC). Summation of the Hazard statement codes for each compounds present in farmed bauxite residue shows no threshold is exceeded for any of the hazard properties (HP) and that farmed bauxite residue is non-hazardous.

8. References

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2. European Chemicals Agency. *Guidance on the Application of the CLP Criteria*, Version 4.1, June 2015. http://echa.europa.eu/documents/10162/13562/clp_en.pdf
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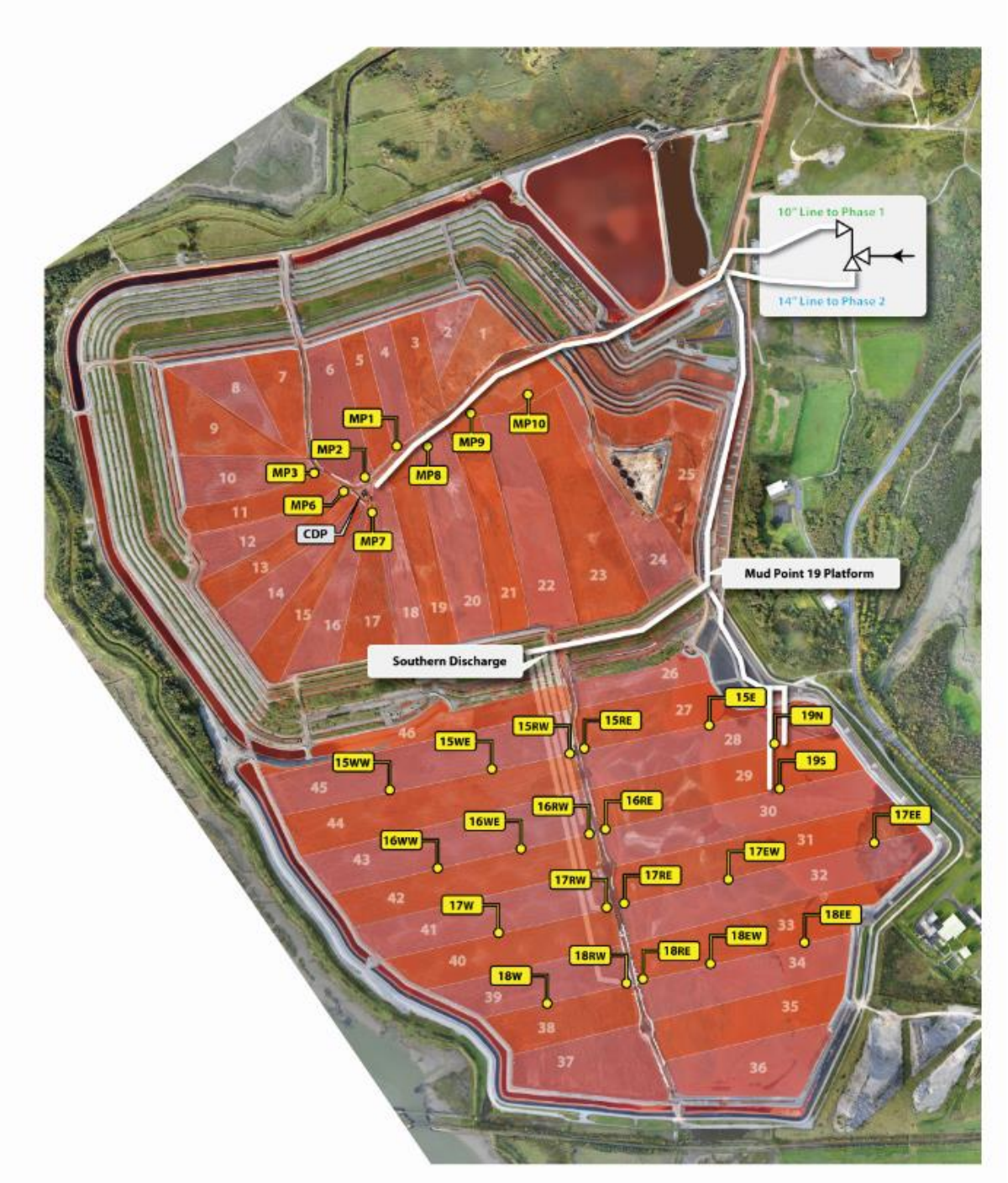
Appendix 5

RUSAL
AUGHINISH

BRDA OSM Manual



Prepared By: Louise Clune	***Approval***			***Reference No.*** ***0SM001***
	Name	***Signature***	***Date***	
Revised by: ***Date:*** *16/08/2018*	BRDA Civil Engineer Env Co-ordinator Technical Manager	Kevin McMahon Louise Clune Donie McEnery		***Issue*** 2 ***Revision*** 1

Contents

1. Introduction

The Bauxite Residue Disposal Area (BRDA) is a dedicated extractive waste facility which is owned, developed and operated by Aughinish Alumina Ltd (AAL) for the permanent disposal of specific bauxite and process residues generated within the alumina extraction facility.

This Operational, Safety and Maintenance (OSM) manual has been developed in accordance with:

i. Industrial Emissions Licence P0035-06 (IE Licence)
ii. Reference Document on Best Available Techniques for Management of Tailings and Waste Rock in Mining Activities 2009
iii. ISO14001:2015 certified Environment Management System (EMS)

The purpose of the OSM Manual is to define the operational, safety and maintenance management systems of the BRDA. It is the responsibility of the BRDA Operations Engineer to update the OSM Manual. All roles defined in the Organisation section of the Manual must be familiar with the systems defined within.

2. Organisation

The Technical, Knowledge Management & Quality Manager (referred to as Technical Manager) who has overall responsibility for the BRDA. Reporting to the Technical Manager is the BRDA Operations Team.

The BRDA Operations Team is outlined below. Job descriptions have been developed for AAL employees and are available on the Organisational Chart.

i. **BRDA Operations Engineer**
Responsible for BRDA operations including health and safety
ii. **BRDA Consultant Civil Engineer**
Technical Advisor for the BRDA
iii. **Designated BRDA Contractor, Murphy's International Ltd. (MIL)**

Responsible for placement of trucked residue material, operation of mechanical equipment to achieve carbonation via mud farming

iv. **Designated Landscaping Contractor (Raleigh's)**
Responsible for harrowing and compaction of bauxite residue, landscaping of BRDA areas, maintenance and planting of vegetation

v. **Environment Technologist** (reporting to Human Resources)
Responsible for supporting BRDA Operations Engineer

The Environment Team (reporting to the Technical Manager) engage with the BRDA Operations Team and the Regulator to ensure the BRDA is operated in compliance with the IE Licence. The Team consists of the Environmental Coordinator, Senior Environmental Engineer, Environmental Engineer and Environmental Technologists, as per Organisational Chart.

Additional resources are provided by the Safety, Public Affairs and Engineering Departments.

Murphy Internal Limited is the Contractor responsible for collection, transportation and placement of residues within the BRDA and residue farming. The contract extends to maintenance and resourcing equipment such as vehicles and dust suppression equipment.

3. Classification

The BRDA has been classified by the EPA (Environment Protection Agency) as a Category A facility under the Extractive Waste Directive (2006/21/EC). This Directive on the management of waste from extractive industries provides for measures, procedures and guidance to prevent or minimise the adverse effects on the environment and risks to health resulting from the management of waste from the extractive industries. The classification was agreed by the EPA as per written correspondence received in 2011.

This classification ensures that the design and operation of the BRDA must provide the highest level of environmental protection possible. Requirements of a Category A facility are:

i. Waste management plan
ii. Major accident plan
iii. Proper construction and management of the facility
iv. Environmental protection measures
v. Closure and aftercare plan
vi. Financial guarantee for closure costs

4. Nature and Quantities of Residues Disposed

Bauxite and process residues (otherwise known as extractive waste) generated within the alumina extraction facility are deposited within the BRDA in accordance with the IE Licence. Bauxite residue is generated following extraction via caustic digestion of alumina species from bauxite ore. Bauxite residue is segregated into 2 fractions - fine bauxite residue and the coarse fraction which is process sand.

Bauxite residue (fine and coarse) represent 90% of total process residue disposed of in the BRDA. Bauxite residue (fine) is subject to counter-current washing and dewatering via vacuum filtration before being pumped as high density slurry to the BRDA and farmed to achieve atmospheric carbonation.

The Table below summarises those process residues disposed of in the BRDA along with the applicable EWC (European Waste Code) code. Farmed bauxite residue is classified as non-hazardous while salt cake is classified as hazardous.

Waste Stream	Description	EWC code
Farmed Bauxite Residue	Residue from Bauxite processing	01 03 09
Process sand	Residue from Bauxite processing. Used for internal BRDA road construction	01 03 99
Salt Cake	Product of liquor purification process.	01 03 07
Lime Grits	Lime slaking rejects. Used for internal BRDA road construction	01 03 99
Process Scales and Sludge	Scale and sludge from vessel and pond cleanouts	01 03 99
Recovered Concrete Rubble	Construction and demolition. Used for internal BRDA road construction	17 01 01
Recovered Refractory Material	Calciner and boiler unit refractory.	16 11 04
Other Recovered Materials	Process contaminated materials e.g. cooling tower packing.	Dependent on plastic type

Refer to the AAL Waste Management Manual for further details on the nature of residues disposed of in the BRDA.

Data on the quantities and chemical properties of residues disposed of in the BRDA are reported in the Annual Environment Report.

Details on the physical properties of bauxite residue are described in a paper entitled 'Closure and Rehabilitation of AAL BRDA'.

5. Operation

Activities and systems associated with operation of the BRDA are defined in the Standard Work Method (SWM) 'Area 54A Operation of the BRDA'.

Note: There are a number of SWM's referred to in this manual which are relevant to BRDA operations. SWM's provide details of responsibilities, activities, performance indicators and records.

The objectives of BRDA operations are:

i. To provide storage for bauxite residue and permitted process residues
ii. To ensure bauxite residue and other process residues generated by the refinery are disposed of safely and compliant with environmental requirements
iii. To farm bauxite residue in order to achieve atmospheric carbonation (densification and pH reduction to < 11.5)
iv. To maximise storage capacity of the BRDA

The atmospheric carbonation of bauxite residue via mud farming is a condition of the Industrial Emissions (IE) License. The use of mud farming machinery, namely amphirolls, to densify and dry the bauxite residue layers (thereby reducing the footprint generation of the residue) and the use of that same machinery to enhance the exposure of the residue layers to atmospheric carbon dioxide (to

reduce the liquid phase alkalinity in the bauxite residue and thereby reduce its pH to < 11.5) ensures that bauxite residue continues to remain a Non Hazardous residue.

Archimedes Screw Tractors or commonly called amphirolls (see image 1 below) are used to plough and densify the bauxite residue by compressing the residue layer as well as increasing the residue surface area to enhance atmospheric drying. The weight and dynamic movement of the scrolls through the bauxite residue squeezes out residual fluid /water in the residue thereby densifying and increasing the solids contents. The drying of the residue is enhanced by the increase in surface area of the residue resulting from the ploughed furrows and ridges. The increase in the surface area of the bauxite residue thereby increases evaporation from the residue as well as increasing the contact area for the residual alkalinity in the residue layer with the atmospheric carbon dioxide - thereby carbonating and reducing the alkalinity and pH of the residue. The BRDA Operations SWM defines the sampling protocol of farmed bauxite residue. A laboratory test method has been developed which outlines the analysis procedure of farmed bauxite residue to confirm pH < 11.5.

In addition a low ground pressure bulldozer (see image 2 below) is used to grade out flat the ploughed furrowed surfaces of the residue prior to the placement of the next layer of fresh residue paste.

Image 1

Image 2

The most recent Site Investigation data (2014) indicates that the moisture content within the farmed bauxite residue ranges from 26% to 38%, whilst the values within the non-farmed bauxite residue range from 31% to 49%. Thus moisture content reduces. The mean dry density of bauxite residue increases from 15.5kN/m^3 in the unfarmed layers to 16.8kN/m^3 in the farmed layers thereby increasing the density of the residue. Triiaxial data indicates that the undrained shear strength of the residue has increased from values at 2% strain of 3kPa to 68kPa in unfarmed layers to 3kPa to 129kPa in farmed layers. Therefore the strength, density and stability of bauxite residue increases with farming by amphirolling. In addition the pH of farmed bauxite residue is reduced to < 11.5.

Control of bauxite residue quality is the responsibility of Local 2 as documented in the SWM 'Minimise Mud Soda Losses and Maximise Mud Density to the BRDA'.

Management of water inventory (perimeter channel and pond levels, inventory, distribution) is documented in SWM 'Water Management'.

Management of fugitive emissions from the BRDA is documented in SWM 'BRDA Dust Prevention and Control'.

The key operating principles of the BRDA are:

i. Only those residues permitted by the IE License are disposed of in the BRDA.
ii. Soda content of residues is minimized, solids content of residues are optimized to maximize storage capacity.
iii. Storage capacity development within the BRDA is achieved by upstream rockfill embankment construction whereby the underlying bauxite residue supports the upper rockfill embankment.
iv. Design is confirmed by the Engineer of Record (Golders) via routine monitoring of pore pressures and movement via inclinometers and continuous penetration testing (refer to SWM 'BRDA Stability'.
v. The integrity of HDPE geomembrane liners is maintained e.g. no mobile equipment is permitted to contact the geomembrane directly.
vi. Water run-off is directed to and collected in the perimeter channels prior to treatment before final discharge.
vii. Downstream drains, external watercourses and groundwater observation wells are routinely inspected as per IE Licence requirements.
viii. SWM 'Incident Response' is applied to ensure remedial action is taken to prevent recurrence.

An internal Sharepoint web page has been developed which provides links to BRDA operations related documents associated with safety, maintenance, planning, recording, reporting, procedures and training.

6. Waste Handling and Placement

For all those waste streams which are outlined below refer to the Waste Management Manual for further details. In addition, refer to the following documentation.

All trucked residues are transported to the BRDA on a network of internal access roads.

Document Ref.	Procedure title/link
SWM 2022	Operation of the BRDA
SWM 2009	Minimize Mud Soda Losses and Maximize Mud Density to the BRDA'
SWM 2006	Sand Separation

The majority of bauxite residue is pumped to the BRDA at > 58% solids.

Process sand (coarse bauxite residue) is trucked to the BRDA by Contractor following washing to reduce soda content.

Saltcake is that residue produced from a liquor purification process which is composed of sodium salts of carbonate, sulphate, oxalate, fluoride and chloride. Saltcake is trucked to the BRDA by Contractor. Saltcake is classified as a hazardous waste and is deposited within a composite lined disposal area within the BRDA, as per the IE Licence.

Lime grits, insoluble clinker, produced from a lime slaking process in Local 1, are trucked to the BRDA by Contractor.

Process scale which is removed from process vessels and pipework from across the plant operations, is trucked to the BRDA by Contractor.

7. Safety Management

The Safety Policy defines the Companies commitment to safety of personnel onsite in accordance with its safety management system which is certified to ISRS (International Safety Rating Standard) Advanced Level 8.

Safety management at the BRDA ensures that:

i. Personnel are protected from particular hazards such as water and soft bauxite residue
ii. The structure is geotechnically stable
iii. Seepage management is monitored

Risk assessments have been documented to manage personnel safety. In addition safety measures such as installation of crash barriers and life buoys as well as use of specialist mobile plant (for travelling on soft residue) are in place.

Refer to SWM 'BRDA Stability' for details of how geotechnical stability is monitored.

An independent Risk Assessment and Break Out study has been completed by Golder Associates. This documents the positive impact of the farming process on improving stability thus reducing the already negligible low probability of the residue to mobilise. Those hazards identified in the study which pose *negligible to highly improbable* risk are:

i. Displacement of alkaline water in the perimeter channel
ii. Slope failure of containment walls
iii. Containment failure based on future sea levels (for the year 2200)

Measures in place to minimise these identified *negligible or highly improbable* risks include:

i. visual inspections
ii. Monitoring of pore pressure, movement and strength of residue and underlying strata
iii. Construction design
iv. Maintaining gradient for drainage
v. Installation of erosion protection
vi. Installation of penstock valve to protect the Robertstown river
vii. Inspection and maintenance of the flood tidal defence berm
viii. Installation of pumping systems to recover the perimeter channel to the storm water pond and to recover perimeter channel no. 2 to perimeter channel no. 1
ix. Flexibility of pumping systems to either the storm water pond or effluent treatment system
x. Resources available 24 hr/7 days/week in the event of pump breakdown

8. Emergency Preparedness

The management of emergencies is coordinated by a fully resourced and trained plant security team who provide 24 hr/7 days/week cover for the entire site including the BRDA Roles and responsibilities are outlined in the following applicable internal emergency response procedures.

Procedure Ref.	Procedure title/link
N/A	Plant wide Emergency Response Plan
P007.02.019	BRDA Containment Emergency Response Procedure
P007.02.012	Dust Emergency in the BRDA
P007.02.017	BRDA High Wind Procedure

P007.02.018	Severe Frost Conditions

In compliance with the Category A classification, an External Emergency Response Plan has been developed for the BRDA by Limerick City and County Council. The objectives of this Plan are:

i. Contain, control and implement measures to protect human health and the environment in the event of a major accident.
ii. Communication of required information to the public, relevant services and authorities.
iii. Provision for the rehabilitation, restoration and clean-up of the environment.

9. Design and construction

The 'Risk Assessment and Break Out study' issued by Golder Associates in 2014 details the design and construction standards underpinning the structural integrity of the BRDA. Key components of the BRDA design are:

i. Low permeability outer perimeter embankment wall
ii. Permeable inner perimeter embankment wall
iii. Perimeter interceptor channel surrounding the BRDA for collection of surface water run-off and seepage
iv. Composite lined Phase 1 extension and phase 2 (original Phase 1 unlined)
v. Stage raises
vi. Upper level bench to reduce overall side slopes
vii. Minimal surface water retention
viii. Upstream method of raising the perimeter wall involving construction on previously deposited and farmed residue

An assessment has been completed of compliance with Best Available Techniques (BAT) for Tailings facilities (Reference Document on Best Available Techniques for Management of Tailings and Waste Rock in Mining Activities 2009. Those design aspects of the BRDA which are considered BAT include:

i. Dry tailings stacking
ii. Minimising volume of tailings generated (via filtration and farming)
iii. Treatment of tailings to remove environmental and safety hazards (via filtration and farming)
iv. Management of water to prevent water erosion
v. Automated sprinkler system for prevention of dusting
vi. Extensive network of monitoring points for groundwater and stability
vii. Minimising seepage generation (via perimeter design, lining and low permeability estuarine silt deposits)
viii. Re-use of surface water run-off (once treated for sprinkler system)
ix. Use a 1 in 200 design flood for sizing of emergency discharge capacity
x. Limestone rock fill chosen for core construction for strength
xi. Application of upstream method for raising perimeter
xii. Minimum safety factor of 1.5 applied
xiii. Program of progressive restoration on outer perimeter walls
xiv. Application of DCS (Distributed Control System) which connects directly to equipment such as pumps and level instruments. Pi Process Book is employed as a data interrogation tool
xv. Management of tailings deposition
xvi. Direct vegetation of dome on closure

Seepage is recovered via a series of recovery wells as per submission made to the EPA in 2015. Seepage loss takes into account losses to ground or groundwater from the BRDA which permeates or flows to existing surface water receptors or groundwater receptors around the perimeter of BRDA Phase I and II. Based on current surface water and groundwater monitoring, there is no seepage from the BRDA escaping to external receptors.

The composite lined hazardous waste cell for saltcake deposition is located on low permeability mature bauxite residue. There is no hydraulic connection between the composite lined cell and the BRDA itself. The design details are documented in construction quality assurance documents as agreed with the EPA.

The storm water pond (SWP) collects runoff from the surface of the BRDA via the perimeter channels prior to treatment in the effluent treatment system. The SWP was raised and relined with a composite lining using a combination of geosynthetic clay liner and processed glacial till on the side slopes, overlain by HDPE liner.

The ELPRO System is a wireless communication system that relays digital and analogue signals between the DCS and the BRDA over a wireless network. It controls the mud discharge to the BRDA using hydraulic power pack stations, pumping utilities from perimeter channels and drains and the sprinkler valves. The Local 2 Electrical Engineer is responsible for maintenance of the ELPRO system.

10. Maintenance

The Plant Maintenance Manual described maintenance management systems in place including residual life and preventative maintenance.

Maintenance of Ponds and Perimeter Channels

Maintenance of Ponds and the perimeter channels (cleanouts and inspections) is documented in SWM 'Pond Cleanouts and Inspections'.

Maintenance of Side Slopes and Vegetative Covers

Daily and weekly inspections ensures detection of potential issues which could cause erosion, piping and deterioration of side slopes and vegetation. If detected, tasks and job tickets will be issued for corrective action. The Engineer of Record will be contacted if substandard conditions are detected which could affect BRDA Stability. In addition the annual inspection and quarterly monitoring by the Engineer of Record will detect if substandard conditions are emerging on the downstream slopes and will report same to the BRDA operations engineer. All civil works issues will be repaired by the BRDA Operations contractor (MIL). Vegetation related works will be repaired by the designated Landscaping Contractor (Raleigh's)

Maintenance of Drainage Systems

Daily and Weekly inspections include monitoring performance of the radial perimeter drainage pipes. These drainage pipes are at approximately 100 metres perimeter spacing and transfer surface water from the downstream side (of the current upper operating stage raise wall) downhill to the perimeter channel. These are visually checked for blockages on the upstream side. The accumulation of silt in the perimeter drainage channels graded towards those radial drainage pipes is removed by excavator if drainage pipes risk being blocked.

The drainage wall on the East Side of the Phase 2 BRDA is inspected to ensure that water ponding on its surface can be lowered by operation of Sweepax pumps at either end of the drainage wall. If water ponding persists, then both the upstream perimeter bund of the drainage wall and the road surface of the drainage wall is inspected to determine if it is blinded by residue fines. If surface blinding is detected it is removed by excavator and fresh drainage stone placed on the excavated surfaces.

Maintenance of Exposed Geomembrane

If defects are detected in the exposed geomembrane, then the Engineer of Record, once informed, prepares the necessary scope of repairs. The repairs are undertaken by the BRDA Operations contractor using a specialist geomembrane lining sub-contractor and the repair is supervised and logged by the Engineer of Record.

Maintenance of Access Roads

The surfaces of the access Roads and main haul roads for the trucked residues are regularly washed and maintained.

Maintenance of Water Pumping Equipment.

All pumps have their own dedicated equipment number and are maintained in accordance with the Plant Maintenance Manual by the Local 2 Maintenance Team.

Maintenance of hydraulically actuated residue Valves for Residue Distribution Systems.

All groups of principal valves have their own dedicated equipment number and are maintained in accordance with the Plant Maintenance Manual by the Local 2 Maintenance Team.

Maintenance of Mobile Mechanical Plant for mud farming and drainage works

Each mobile mechanical equipment has a dedicated equipment number and is maintained in accordance with the Plant Maintenance Manual by the Aughinish Mobile Pool Team for general maintenance tasks and by the Manufacturers service operatives for particular maintenance tasks as organised by the Aughinish Mobile Pool Team.

Maintenance of Sprinkler Systems

Routine checks of the sprinkler system carried out by the BRDA Operations team include:

i. Correct operation of sprinkler valves and pumps
ii. Flow and pressure meeting set points
iii. Correct rotation of sprinkler heads
iv. Correct height of sprinklers for coverage

Deviations from target are followed up with Local 2 Operations Equipment Facilitator (OEF) regarding valves and pumps and BRDA designated contractor (MIL) regarding sprinkler height and heads.

Maintenance of ELPRO System

On a monthly basis each panel connected to the ELPRO System is inspected by Local 2 for water ingress, tidiness, correct drawings and adequate working lighting. Refer to the ELPRO system maintenance description for further details.

11. Monitoring

Extensive monitoring of the BRDA is carried out as per IE Licence requirements and in accordance with the SWM 'Environmental Monitoring and Reporting' and 'BRDA Stability SWM'. Refer to the Annual Environment Report for further details.

12. Life Expectancy, Closure and Aftercare

The life expectancy of the combined Phase 1 and 2 BRDA is 2032, based on current production and residue generation levels. This is detailed in the Annual Environment Report.

Closure, restoration and aftercare of the BRDA is documented in the Closure, Restoration and Aftercare Management Plan (cramp) issued by PM group in 2018 and submitted to the EPA.

Closure will involve application of techniques which have been demonstrated via extensive research programs including field trials. The key elements is rehabilitation cover via direct remediation of the farmed bauxite residue as presented at the 2017 ICSOBA Conference.

Closure for the saltcake cell are also defined in the 2018 CRAMP report. A double plastic HDPE liner will be placed over the cell at closure to seal in the saltcake. A drainage layer, subsoil and topsoil will be placed over the liner and the surface will be vegetated with grass.

The preferred final land use for the BRDA is to develop the area for nature conservation.

Appendix 6

Bauxite Residue Disposal Area Rehabilitation

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Abstract

The Rusal Aughinish Alumina (AAL) refinery is located on Aughinish Island, on the southern shore of the Shannon Estuary 33 kilometres west of Limerick city in the South West of Ireland. The plant, which commenced operation in 1983, is currently producing 1.965Mt/yr. It sources bauxite predominantly from Guinea, Brazil and Guyana and uses the Bayer process to produce Alumina. The refinery functions with an accredited Safety Management System (ISRS), Environmental Management system (ISO14001), Quality Management System (ISO9001) and Energy Management system (ISO50001). The bauxite residues generated from the Bayer process are deposited in an engineered facility called the Bauxite Residue Disposal Area (BRDA). The operation of the BRDA is one of the key enablers to execute the BRDA closure plan. Partial neutralisation of the mud by atmospheric carbonation through mud farming produces a mud with pH<11.5 which is suitable for remediation and revegetation. The preferred land-use option post closure, based on current knowledge of the chemistry and biology of the sown grassland cover, is to develop the area for nature conservation. This paper outlines the field studies, which have demonstrated that bauxite residue can be successfully rehabilitated.

Keywords: Alumina refinery, BRDA, bauxite residue, rehabilitation.

1. Introduction

Rusal Aughinish Alumina (AAL) refinery is located on Aughinish Island, on the southern shore of the Shannon Estuary 33 kilometres west of Limerick city in the South West of Ireland. The plant, which commenced operation in 1983, has a current production capability of 1.965Mt/yr. It sources bauxite predominantly from Guinea, Brazil and Guyana and uses the Bayer process to produce Alumina.

Green alumina has a key role to play in creating green aluminium. The production of green alumina at AAL is key to the environmental sustainability of the refinery. This sustainability is multi-faceted and includes bauxite residue disposal management, continuous monitoring to ensure there is no impact on the local environment and minimisation of CO_2 emissions [3].

This paper outlines the approaches taken by Aughinish to achieve revegetation and support ecosystem development on bauxite residue. The refinery at Askeaton, Co. Limerick currently produces approximately 1.37 Mt of bauxite residue per annum, which is stored in a Bauxite Residue Disposal area (BRDA) of 183 ha.

Rehabilitation involves amendment with a carbonation process to neutralise the pH, following this, gypsum and residue sand is effective in improving physico-chemical properties and promoting seedling establishment and growth. Application of compost is used to overcome the nutrient deficiencies of the residue [1]. Years of research in conjunction with the University of Limerick have established with this combined approach, several grassland species have successfully grown on the residue enabling the primary restoration goal to be achieved [1]

Conditions issued by the Environmental Protection Agency (EPA) outlined in the Industrial Emissions License (IE) stipulate that a closure scenario be enacted on a dedicated section of the BRDA to demonstrate that developed methodologies are adequate to successfully achieve closure. For the past 20 years AAL have a successful monitoring programme in place to demonstrate the success of the vegetation cover system. The establishment of a sustaining vegetation cover is the preferred method for post-closure management of the residue storage area to rehabilitate the residue, improve its aesthetic impact and develop an area for nature conservation

Since 1996 in conjunction with the University of Limerick, AAL have conducted a series of revegetation trials on the residue both at laboratory and field level to develop a revegetation programme and a revegetation recipe for the management of residue in the BRDA.

2. Residue Processing at AAL

The residue is dewatered by vacuum filtration to a solids concentration of 58 % before being slightly diluted and transported, by a 2km pipeline, to the BRDA where it is discharged, spread and allowed to consolidate and dry in layers. Two-metre high rockfill embankments form a stable boundary to stack the layers and increase the BRDA in height.

2.1. Atmospheric Carbonation

There are several stages to post deposition treatment. As mentioned after vacuum filtration, the residue is diluted with water, sheared, thinned in an agitated tank and then pumped as a 58 % solids paste to the BRDA. In this state, the deposited residue cannot yet be traversed by conventional machinery and first must be dewatered and compacted. An amphibious vehicle called an Amphirol is employed to carry out this de-watering and compaction process known as farming.

The Amphirol travels using scrolls, to allow the vehicle to move through the residue. As the Amphirol travels, it compresses the residue and creates tracks or furrows. These furrows allow the water, which has been “squeezed” from the residue to drain along the sloping stack towards the perimeter wall of the cell and into the perimeter channel.

Once the residue has compacted to > 70 % solids by multiple passes of the amphirol, the surface is then graded by a bulldozer to level the surface and generate a constant gradient from the discharge (high point) to the perimeter wall (low point). This makes the residue suitable for conventional agricultural machinery to travel and operate on its surface. Atmospheric carbonation of the residue by the amphirol and agricultural machinery allows for exposure of the residue to CO_2 in the air. Sufficient exposure and carbonation reduces the causticity below 30% and reduces the residue pH below 11.5. This is the mechanism by which the residue is exposed to atmospheric CO_2. Once carbonation is completed as evidenced by pH measurements of samples from the cell, the area is then re-graded using a bulldozer to remove any depressions. The cell is then ready for the subsequent layer of bauxite residue.

3. Legislation

Although earlier planning permissions granted to the refinery contain requirements with respect to landscaping and restoration of the BRDA, the Integrated Pollution Prevention Control Licence (IPPCL) introduced in 2008 issued by the EPA contained many stringent conditions for BRDA restoration and aftercare. Since its issue in 2008, the licence has been updated in 2012 and most recently in 2014 to the Industrial Emissions License (IE P0035-06). Over the years,

the major change has been the introduction of partial neutralisation of the residue surface by farming which is a well-established practice at AAL.

Conditions stipulated in the IE issued to Aughinish state that revegetation work be continued on the BRDA and findings reported in the Annual Environmental Report (AER) and sustainability issues of the revegetation system be determined (Condition 8.4.20). Provision of a dedicated research trial cell for demonstration of the proposed closure technique for the residue is a licence condition (Condition 8.4.22).

Figure 1. Farming with Amphirol.

4. Rehabilitation History at AAL

Rusal Aughinish in collaboration with the University of Limerick in 1996 implemented a series of revegetation trials on the BRDA to develop a restoration technique that can be established on the residue and to demonstrate the effectiveness and sustainability of the closure technique. The sequence of trials will now be discussed; an overview of the trial locations is shown in Figure 2.

Figure 2. Overview of BRDA and Area where trials have been carried out.

Table 1. Legend.

Reference in Paper	Description
Section 4.1	Early trail plots 1996 - 2007
Section 4.2	Larger trails 2007 - 2011
Section 4.3	First cell trial plot 2008/2009
Section 4.4	Terraced area rehab and grassing 2015
Section 4.5	New demonstration cell
Section 6	Side slope rehabilitation 2013

4.1. Early Revegetation Trials 1996 - 2007

The BRDA is designed using an upstream system using 2m high rock embankments. The rock lifts are terraced in an upstream fashion to increase the height of the BRDA and manage the disposal of residue. Consequently, available space for the initial revegetation work was restricted to terraced areas between the raises (see Figure 2). The restoration strategy adopted on the BRDA was to seed temperate grassland species on amended residue with a view to establishing amenity type grassland that is sustainable. A series of revegetated areas were implemented on these terraced areas during 1996-2007 as outlined below.

Table 2. Experiment History.

Year	1996 - 1999	1997-1999	2000-2005	2006	2007
Experiment type	Laboratory characterisation and Greenhouse trials on bauxite residue and amended bauxite residue.	Field experiment testing effect of amendments on residue properties and Plant uptake in revegetated residue	Continued field experiments testing efficiency of revegetation methods employed in 1997 - 1999.	Field experiments investigating variations of the procedure to optimise conditions for preparing residue prior to seeding	Larger scale field experiments on a 0.6 ha site demonstrating revegetation prescription is effective on residue typical of a closure scenario

Different scenarios were experimented with during the early trials. Plots were fully treated amended with gypsum, process sand, spent mushroom compost and seeded with a grassland mix. Partially treated plots were amended only with process sand, spent mushroom compost and then seeded. Other plots were left untreated [3].

The revegetation recipe now used at AAL is based on the success of these trials. Residue that was treated and revegetated between 1996 and 1999 was surveyed in 2005. Species diversity was recorded and compared to the initial seed mixture of 6 species [1].

- There were 50 species belonging to 40 genera and 16 families.
- Asteraceae and Poaceae were the dominant families.
- Seven leguminous species were recorded growing.
- Dominant grass species were Holcus lanatus with Festuca rubra and Agrostis stolonifera.
- Woody species Betula, Salix and Alnus established on the revegetated areas.
- Patches of hay, spread on residue surface acted as a seed source [1].

The trials also have demonstrated that addition of process sand and gypsum is effective in lowering uptake of Na, Al and Fe in plants [1].

A detailed investigation of the trial area was also carried out in 2015 in collaboration with the University of Hull and Leeds, the findings of these tests are discussed in section 5 below.

Figure 3. Early small plot trials experimenting different amendments.

4.2. Large Scale Field Trial Implementation 2007 -2011

Previous field trial work conducted on the bauxite residue at Aughinish focused on small level ($2m^2$) plots. A series of large-scale trials were implemented in 2007 to develop practices for residue amendment and seedbed preparation at large-scale level. Findings from this work shows that the key stages in the revegetation programme can be achieved at a large-scale level. These include the ability for the residue to support movement of traffic [2].

A range of grassland species can be used in the seeding once the inhibitory properties of the residue are overcome and a seedbed with adequate nutrients and organic matter is established [2].

Due to the success of the trials and experiments onsite methodologies for optimising plant establishment on the bauxite residue are now well developed:

- Addition of process sand to improve texture and structure of the residue substrate, gypsum for reducing pH and exchangeable sodium (ESP) and organic matter for nutrients are essential components of the revegetation prescription.
- Several indigenous species are capable of growing in amended bauxite residue.
- Effective amendment of the residue results in lower plant content of Na, Fe and Al
- Nutrient cycling in the residue is seen a critical parameter to demonstrate that the vegetation cover is self-sustaining cover. [2]

Lack of organic matter and nutrient deficiency is recognised as a limiting factor in establishing vegetation on any soil including residue. Incorporation of organic matter into the rooting medium is a critical component of the revegetation prescription [2].

Figure 4. Selection of species growing on revegetated residue.

4.3. First Cell Trial Revegetation of Residue

A large-scale (0.6 ha) dedicated research trial cell was constructed in 2008 to test rehabilitating unfarmed residue. The lined cell was filled with fresh bauxite residue and underwent amendment as per the developed restoration technique (i.e. process sand, gypsum, organic matter, and organic matter). Revegetation was undertaken in September 2009, the amended area was seeded with species that had previously been trialled at small plot and large plot scale.

Key research areas within this trial area were:

- Vegetation establishment, survival and succession.
- Vegetation productivity, sustained growth and structure development.
- Fauna colonisation and habitat development.
- Ecosystem processes such as soil development and nutrient cycling.
- Colonisation of specific fauna groups that are involved in these processes.
- Microbiological studies e.g. colonisation by mycorrhizal fungi and microbial biomass [1].

The cell area is sampled bi-annually to monitor the emerging plant/residue soil system and assess functioning ability of the system. It is proposed that this system can be proven sustainable / self-regulating [1].

Based on results and observations from residue research field trials the surface residue (0-15 cm) pH and exchangeable sodium (ESP) indicates improvement in residue properties following amendment, seeding and subsequent soil development. [1]

As previously found, amendment procedures resulted in sufficient macro nutrient supply and there was no evidence of excessive uptake of elements associated with bauxite residue (e.g. aluminium or sodium). Courtney [1] states that:

"Decline is herbage N content observed in the third year is typical of restored sites receiving no further nutrient inputs and is sufficient for the grass sward cover. Other restored residue areas on the BRDA that are 18+ years old exhibit similar N content. Decline in herbage Na content in the third year has also been previously recorded on restored residue sites and is indicative of further improvement of the residue as a soil medium."

Figure 5. Cell five months after seeding.

Figure 6. Cell 10 months after seeding.

Figure 7. Soil Profile of amended and seeded residue after 3 years in trial cell.

4.4. Grassing of Terraced Area on BRDA

As part of a continuous improvement program a new area of the BRDA was rehabilitated in conjunction with Enrich Environmental Ltd. The area chosen was approximately 30m wide at an elevated location on the BRDA stack, in total 4 hectares of residue were seeded. Since its seeding, the area has been continually monitoring for grass growth (See Figure 3).

The aims of the work undertaken in 2015 were:

1. To establish grass on the wide terreaced area of the BRDA; and
2. Monitoring and maintaining the grass.

Analysis was undertaken in 2015 to characterise the bauxite residue. From the results of the characterisation, an inclusion rate of customised organic matter along with an incorporation depth and application method was devised. The organic matter provision was to provide the nutrients for grass establishment.

In 2015 the following was conducted:

- Addition of gypsum to the surface 3%
- Customised organic matter was incorporated at a rate of 30% and sown with the following nine salt tolerant grass species:
    - Creeping Bent
    - Common Bent
    - Crested Dog's Tail
    - Sheep's Fescue
    - Red Fescue
    - Perennial Rye grass
    - Salt Marsh Grass
    - Red Clover
    - White Clover [4]

A drainage plan was designed and a management plan for the established grass area was implemented. This involved mowing the grass 2-3 times during the year to return the nutrients to the ground. The ground was aerated as required.

Nine salt tolerant grass species were sown and grew well, the grass continues to thrive and currently presents a green belt along the north and west of the BRDA perimeter. This result shows that it is possible to establish grass on the BRDA. Aeration is required to ensure that the activate root zone remains aerated, due to compaction a hard pan can develop resulting in restricted movement of the roots limiting the plants access to vital nutrients [4].

Figure 8. Steps in rehabilitation and revegetation of deposited residue in terraced area.

Figure 9. Terraced area demonstrating healthy grass growth.

4.5. Rehabilitation of Farmed Residue

During 2017 AAL are constructing a new closure demonstration area which complies with condition 8.4.21 of the IE P0035-06 [8]. This condition states that;

"*The final lm of all exposed red muds deposited in the BRDA shall comprise 'amended mud'. This 'amended' layer shall include a proven composite of neutralized process residues, sand, gypsum and organic material. The amendment layer shall be underlain by a capillary break layer of process sands or equivalent approved. AAL shall continue to operate a dedicated trial research area for closure/revegetation research. Annual progress reports on research findings, and operational decisions flowing therefrom, shall be reported as part of the Annual Environmental Report*."

The cell is currently in the construction phase and when completed it will demonstrate the use of a capillary break and an amended layer for vegetation. The function of the capillary break is to prevent liquid or seepage from the residue making its way to the surface through capillary action. There will be two test areas formed within the cell to monitor the effectiveness of different types of capillary breaks (capillary break with crushed limestone material and neutralized process Sand).

The amended layer will be constructed from carbonated residue, neutralised process sand 25%, gypsum 3% and organic material 20%; the trial area will also be used to test the effectiveness of the amended layer without gypsum.

Once constructed this cell will reflect a typical closure scenario of the BRDA. To demonstrate its sustainability and comply with the license conditions it will be intensively monitored.

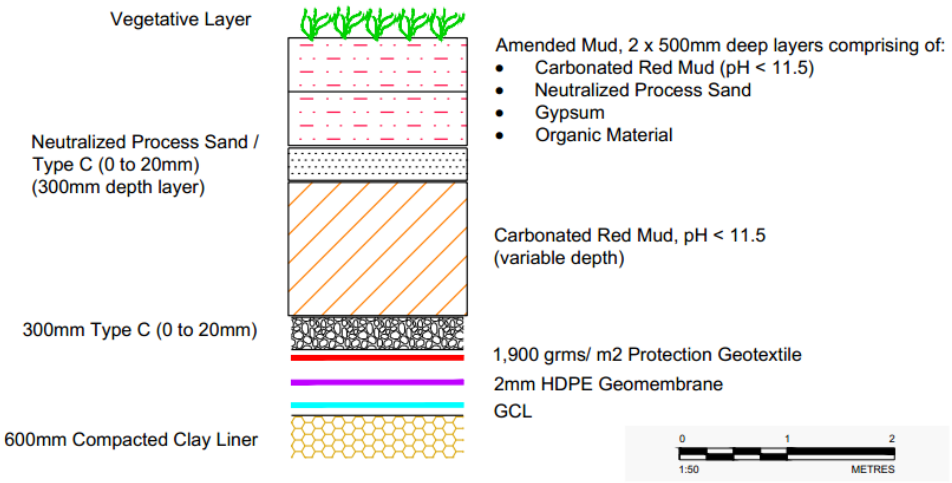

Figure 10. Section through new closure demonstration cell.

5. Sustainability of Remediated Bauxite Residue

In September 2015 in collaboration with the University of Hull and Leeds, trial pits were dug at 5cm intervals to a depth of 50 cm in the revegetated plots seeded in 1999 on the BRDA, sampling was undertaken 20 years after deposition and 16 years after treatment. Three plots within the BRDA were investigated. The fully treated plot which was amended with gypsum (3% w/w rotavated-in to a depth 30 cm), process sand (10% w/w rotavated-in to a depth of 30cm), spent mushroom compost (80t Ha^{-1} rotavated-in to a depth of 20cm), and seeded with a grassland mix (100 kg/ha) [3]. The partially treated plot which was amended only with process sand, spent mushroom compost, and then seeded. The third plot was left untreated. Samples of bauxite residue were collected to a depth of 50 cm from the trial pits in each of three different treatment zones [3].

5.1. Sampling Observations

Both the fully treated and partially treated sites were vegetated with a variety of perennial grasses (Holcus lanatus), trifoliate clovers (Trifolium pratense), and occasional small shrubs. The untreated plot was largely unvegetated with one or two areas of stunted grasses. The root zone of the fully treated and partially treated sites extended approximately 15 cm beneath the surface, and below 20cm the substrate had the appearance of dewatered bauxite residue with little change in appearance to 50 cm depth. The untreated profile had no root zone and at all depths had a very similar appearance to the residue in the other profiles at depths below 20 cm [3].

The pH of the treated plots was notably lower. The plots exhibited a decrease of 2.5 pH units at a given depth, compared to the untreated plot, giving the surface zone of the treated plots pH <8. The treated plots also displayed a 3 – 4 fold decrease in aqueous available sodium at all depths. Treatment also decreased the overall availability of trace metals Al, V, and Cr to 50 cm, compared to the untreated plot. These tests proved that the positive effects of treatment extend well beyond the 20 cm deep treatment zone, and are evident by the lush vegetation growing on the surface [3].

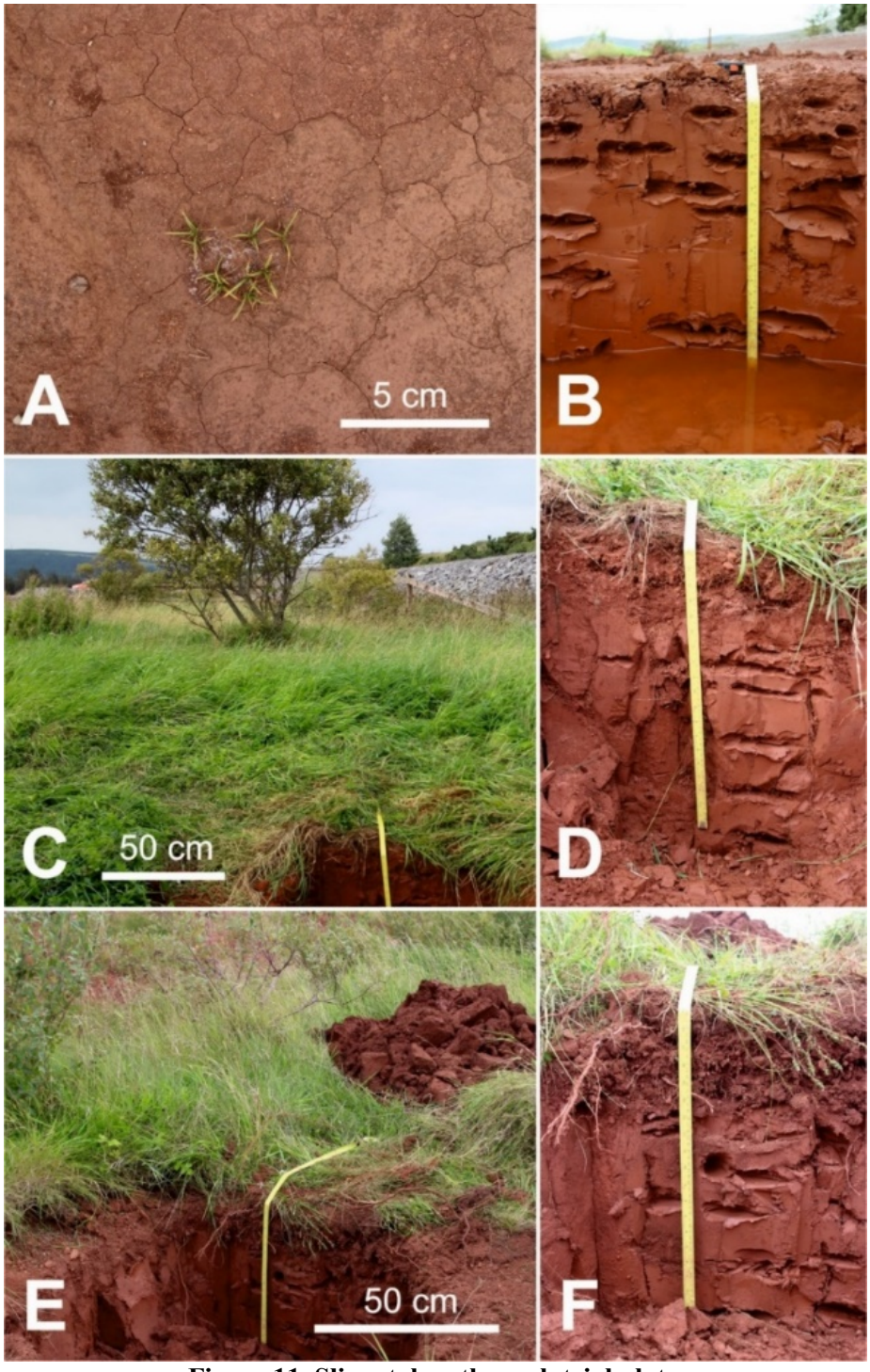

Figure 11. Slices taken through trial plots.

Untreated bauxite residue 20 years after deposition (A, B); bauxite residue 16 years after full treatment with gypsum, organic matter, and process sand (C, D); and bauxite residue 16 years after partial treatment with organic matter and process sand (E, F). The tape measure in B, D, and F measures 50 cm depth in each trial pit [3].

6. Side Slope Rehabilitation

A side slope rehabilitation programme of the BRDA was undertaken in 2013 to improve drainage and visual impact of the area (see Figure 2 overview). The objective was to establish a relatively dense green vegative cover and to establish a dispersed and relatively low-level scrub style planting. The planting has a random and naturalistic appearance when viewed from areas surrounding the structure. The total area for revegetation was 36,870m² in which over 4,000 trees and scrubs of varying species were planted. Many plant species have also naturally developed on the side slopes of the BRDA improving the naturalistic appearance. Side slope rehabilitation differs from dome rehabilitation, as the residue is not directly amended. A layer of drainage stone is first placed on the residue surface followed by subsoil and top soil. Brady Shipman Martin Ltd in conjunction with Golder Associates Ltd designed the drainage and landscaping system. AAL have a proactive landscaping program that targets the appearance of the BRDA and each year invest heavily on planting to improve the visual impact.

Figure 12. Side slope rehabilitation.

7. Final Land Use

The long-term sustainable land-use of the BRDA is the goal for the rehabilitated facility. In deciding the most suitable end use for the BRDA, it has been determined that activities which may lead to over-grazing, poaching, cultivation, uprooting of trees by wind-blow and other surface disturbance will be avoided. The preferred land-use option, based on current knowledge of the chemistry and biology of the sown grassland cover, is to develop the area for nature conservation [5].

AAL operates in a rural, agricultural area bordering areas of special conservation. A section of AAL land to the north of the BRDA has already been developed as a Bird Sanctuary and there are also butterfly and dragonfly sanctuaries on site. Areas to the east of the BRDA are used as nature trails for walking and jogging. The relationship of Aughinish with the local community is paramount to having a Social License to Operate. The final development of a nature conservation area is in keeping with AAL's relationship with its local community [5].

Figure 13. Evidence of thriving ecosystem on revegetated residue (trial 2007 -2011).

8. Conclusion

The establishment of a sustained vegetation cover is the preferred method for post-closure management of the residue storage area to improve its aesthetic impact. Effective BRDA residue farming is the key enabler to achieve this.

Establishment of vegetation on the bauxite residue stored at the BRDA has been successfully demonstrated by laboratory, greenhouse and field trial studies undertaken by AAL, University of Limerick and the University of Hull and Leeds. To achieve this, amendment of the residue is required and an understanding of the basic physical and chemical principles for reclaiming alkaline residues has been established.

The underlying principles of remediation are:

- Creation of drainage channels to assist in drying of the residue
- Partial neutralisation by farming of the bauxite residue to reduce pH
- Application of process sand to improve texture and structure of the residue substrate
- Amendment with gypsum ($CaSO_4$) to replace entrained sodium with calcium
- Addition of nutrients (compost)
- Seeding with native grass and cultivar species.

Field trials have demonstrated that re-vegetation can be achieved through a process of physical and chemical amendment of the residue. A number of treatments were implemented to investigate performance levels of vegetation growing directly on the surface of the residue. Optimum performance was produced by physically amending the substrate with process sand and gypsum.

Previously revegetated residue areas were surveyed after 6 and 8 years. Species diversity was recorded and compared to the initial seed mixture of 6 species. The survey showed significant increase in biodiversity and that there were 50 species belonging to 40 genera and 16 families

and indicates that colonisation by further species occurs on areas once vegetation is established [1].

The extracted DNA concentrations from treated bauxite residue are within the range of extracted DNA concentrations from natural soils, treated bauxite residue has been shown to contain diverse soil-like bacterial communities [3].

At a portion of the financial cost of a traditional cap and cover remediation, these treatments provide a cost effective and viable solution to BDRA closure and residue rehabilitation.

In conclusion, research has shown that vegetation can be successfully grown on bauxite residue, giving a sustainable vegetation cover come closure. AAL have been and continue to be proactive in researching suitable capping methods and demonstrating its success. Strict licensing conditions coupled with ongoing research will ensure an environmentally viable capping method at Aughinish. The overall environmental footprint at AAL ensures that there is no impact on the environment and the community.

9. References

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