2019 Annual Performance Report

Aberthaw Quarry Ash Disposal Site

Permit Number: BP3339BH

March 2020

RWE
The energy to lead

Summary

This document gives details on the performance of Aberthaw Quarry Ash Disposal Site over 2019, as required by condition 4.2.1 of the site's Environmental Permit (EP), BP3339BH.

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1. Operational Update

Aberthaw Quarry Ash Disposal Site (AQADS) is being constructed and filled with Pulverised Fuel Ash (PFA) in four distinct phases (see Appendix A). Phase 1 was constructed in 2008, filled between Quarter 4 2008 to Quarter 4 2010 and then capped and hydroseeded in Spring 2011. Phase 2 was constructed in 2009/10 with filling commencing from Quarter 4 2010. Phase 2 East was filled until Quarter 3 2013 before being capped and hydroseeded whilst Phase 2 West was filled until Quarter 4 2014 before being capped and hydroseeded. Phase 3A (east) was constructed in 2012/13 with filling commencing in Quarter 3 2013 and remained the working phase throughout 2014 and 2015. The construction of Phase 3B (west) was completed in 2014 with filling commencing in Quarter 2 2015. In 2016, Phase 3A and Phase 3B remained as the working phases. In quarter 1 of 2017 ash disposal continued into phase 3B as usual until the last week of March when the Power Station transitioned to 'Summer Cold' status i.e. zero electrical generation and hence zero ash production. The Summer Cold period lasted until November after which a small volume of electrical generation occurred which required circa 2.5kt of ash to be deposited in the Quarry in December. During 2018 13,503 tonnes of PFA deposited in the quarry during Q1 (12,606 tonnes) and Q4 (897 tonnes).
The Power Station operating pattern for 2019 was similar to that of 2018 with a small amount of generation during Q1 & Q4, a total of 1,568 tonnes of PFA was deposited in the Quarry during the year

2. Review of Results for Emission Monitoring

2.1. Hydrogeological Risk Assessment HRA Review

In accordance with the BP3339BH Permit requirement a 6 yearly review of the HRA was carried out during late 2017 and into 2018. The purpose of the review is to determine whether there has been any significant change in conditions at the site and whether the site remains in compliance with the Environmental Permitting Regulations. The review was carried out by an external specialist consultant which in this case was Caulmert Ltd. The review process included an initial meeting between the consultant and RWE staff followed by a detailed review by the consultant of monitoring data gathered since the previous review.
The main conclusion from the review was that there is a discernible presence of PFA identifier species e.g. Molybdenum, Boron, Ammonia in both surface and groundwater but that the higher concentration in the surface water suggests the source of contamination is mainly driven by surface water run off which then effects the groundwater in some but not all boreholes. Work has already been completed at the Quarry site to mitigate this effect by constructing new drainage ditches and channels. It was also recognised in the review that the final restoration plan would ensure all surfaces would be capped and seeded to consolidate the PFA and ensure any run off would be free of contamination.

2.2. Groundwater Quality Review

<u>Monitoring Objective</u>

To carry out routine monitoring of groundwater to monitor the performance of the ash disposal site by measurement of absolute levels and concentrations and trends relative to relevant criteria including background levels and concentrations, control levels and compliance limits.

Number and Location of Monitoring Points

A summary of the monitoring boreholes is provided in Table 1 below and the locations are shown in Appendix A. In January 2015, borehole improvement works were completed to improve water sampling. E05-03 and E06-01were re-drilled (new details provided in Table 1) and the top hat cover was replaced on E06-05. In addition, a new borehole was installed above Phase 3B, E15/1 to improve the understanding of groundwater quality potentially flowing into the site from the south-east. In total, there are 12 boreholes in natural ground, all completed in the Porthkerry Member limestone.

Groundwater flow beneath the ash disposal site is directed towards the cement work lagoons and the River Thaw to the west. Hence, monitoring boreholes, E09-01A, E09-01B, E09-02A and E09-02B on the north-eastern site boundary (approximately 200m apart) are upgradient. Borehole E15/1 on the south site boundary is also upgradient.

Monitoring boreholes along the western site boundary (E05-03, E05-04 and E06-01) with an average spacing of 100m are downgradient of the Pulverised Fuel Ash (PFA) disposal area (Phase 1 and 2). Along the south-western site boundary, two of the monitoring boreholes with an average spacing of 100m (E06-02 and E06-03) are downgradient of the current active PFA disposal area (Phase 3A & 3B) and a future filling phase (Phase 4). Whilst the two remaining boreholes (E06-04 and E06-05) with an average spacing of 100m may be downgradient of a future filling phase (Phase 4).

Table 1: Summary of Monitoring Boreholes

Monitoring Borehole	Formation Sampled	Lithology Type – Natural (N)	Response Zone Depth (m b GL)	Designation
E09-01A	Limestone	N	18-24	Upgradient
E09-01B	Limestone	N	24-30	Upgradient
E09-02A	Limestone	N	21-27	Upgradient
E09-02B	Limestone	N	27-33	Upgradient
E15-1	Limestone	N	17-29	Upgradient
E05-03	Limestone	N	3 - 15	Downgradient Phase 1&2 Active Area
E05-04	Limestone	N	2.5 - 20	Downgradient Phase 1&2 Active Area
E06-01	Limestone	N	3 - 15	Downgradient Phase 1&2 Active Area
E06-02	Limestone	N	2 - 10	Downgradient Phase 3A & 3B Active Area
E06-03	Limestone	N	2 - 10	Downgradient Phase 3A & 3B Active Area
E06-04	Limestone	N	2 - 10	Downgradient Future Filling Phases
E06-05	Limestone	N	2 – 8	Downgradient Future Filling Phases

m b GL – metres below ground level

Monitoring Measurements

The groundwater monitoring analytical suite contains a range of parameters which are monitored on a quarterly basis along with the groundwater level and standard field measurements in accordance with the Environmental Permit. An independent external contractor is responsible for the sampling of the groundwater boreholes and an independent external laboratory is responsible for the analysis of the samples. There have been no changes to the contractor for the groundwater sampling and one change to the analytical laboratory from Q2 2010. Table 2 summarises the changes to the groundwater sampling method since monitoring began to improve the sample quality.

Table 2: Summary of Groundwater Sampling Methods

Monitoring Borehole	Purge Strategy	Purge Equipment	Date From	Date To
E09-01A, E09-01B, E09-02A, E09-02B, E05-04	1 x Well volume	Bailer	Quarter 1 2006	Quarter 2 2013
	Low flow steady state	Submersible pump	Quarter 3 2013	PRESENT
E05-03	1 x Well volume	Bailer	Quarter 1 2006	Quarter 3 2012
	1 x Well volume	Inertial pump	Quarter 4 2012	Quarter 2 2013
	Low flow steady state	Submersible pump	Quarter 3 2013	PRESENT
E06-01	1 x Well volume	Bailer	Quarter 1 2006	Quarter 2 2012
	1 x Well volume	Inertial pump	Quarter 3 2012	Quarter 2 2013
	3 x Well volume	Inertial pump	Quarter 3 2013	Quarter 4 2014
	Low flow steady state	Submersible pump	Quarter 3 2013	PRESENT
E06-02, E06-03	1 x Well volume	Bailer	Quarter 1 2006	Quarter 2 2012
	1 x Well volume	Inertial pump	Quarter 3 2012	Quarter 2 2013
	3 x Well volume	Inertial pump	Quarter 3 2013	Quarter 3 2014
	Low flow steady state	Submersible pump	Quarter 4 2014	PRESENT
E06-04, E06-05	1 x Well volume	Bailer	Quarter 1 2006	Quarter 2 2013
	3 x Well volume	Inertial pump	Quarter 3 2013	PRESENT

Figure 1 shows the recorded groundwater elevations for the previous 14 years which vary between +17 (E05-03) to +35m OD (E05-02B). Upgradient groundwater elevations are characterised by larger amplitude seasonal water level fluctuations with annual winter influxes of rainfall recharge. Downgradient groundwater elevations fluctuate only slightly due to effect of dewatering from the Quarry which maintains groundwater at near-constant elevations.

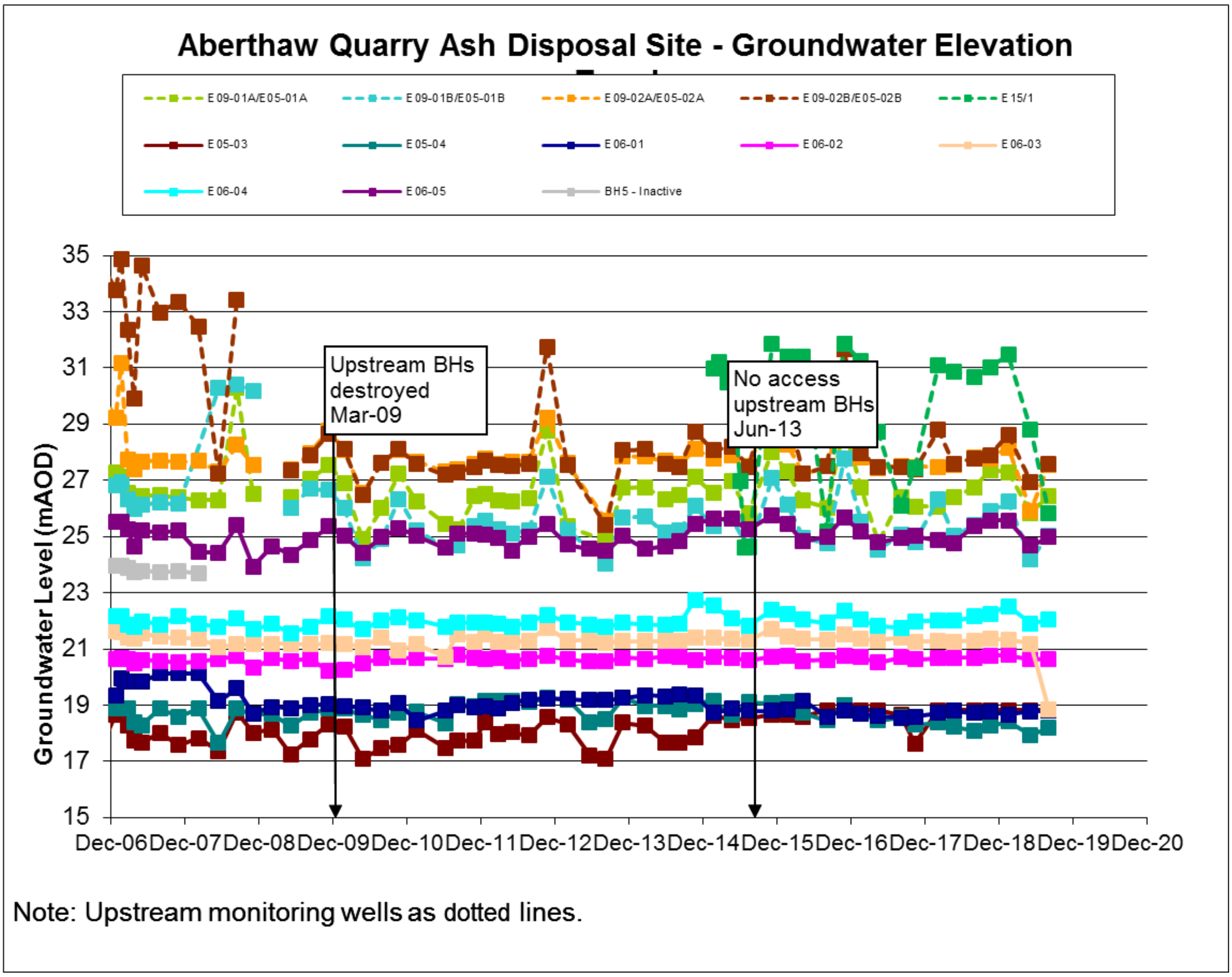


Figure 1: Groundwater Hydrograph

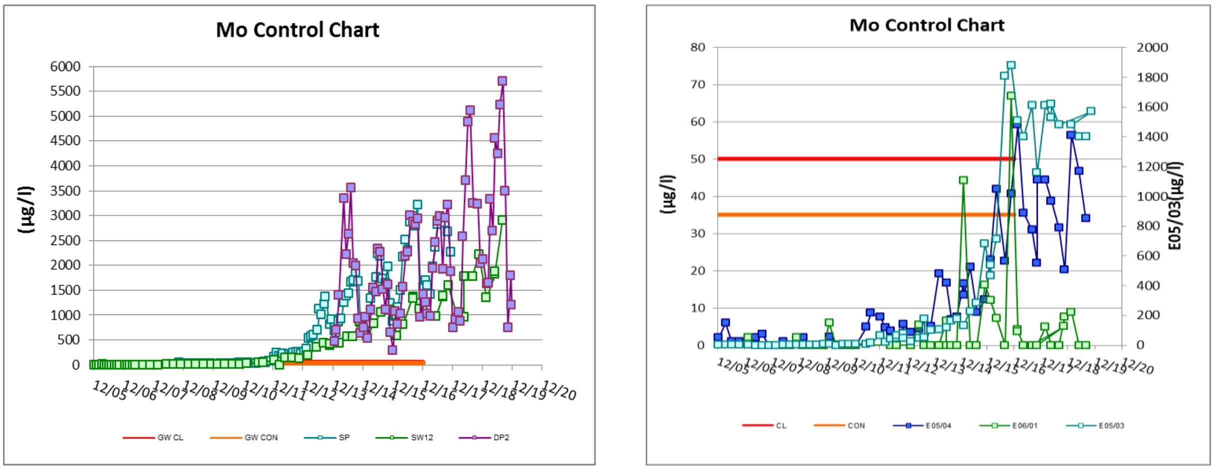
Figure 2 shows the general groundwater quality for the major ions in each of the groundwater boreholes. Natural groundwater quality varies between upgradient and downgradient groundwater. Calcium is depleted in downgradient boreholes, E05-03, E05-04, E06-01 and E06-02 and correlated with elevated sodium, suggesting ion exchange reactions are occurring along the groundwater flow path. Whilst in downgradient boreholes, E06-03, E06-04 and E06-05, major ion chemistry is distinctly different with elevation of calcium, magnesium and sulphate, suggesting a natural geological or quarry-related source in or upgradient of this area.

Figure 3 shows the groundwater control charts with concentrations of all downgradient boreholes plotted as well as the average upgradient concentration (representing concentrations in boreholes E09-01A, E09-01B, E09-02A and E09-02B i.e. background groundwater quality). It should be noted that the compliance limits apply to boreholes E05-03, E05-04 and E06-01 whilst the control levels (where defined) apply to all downgradient boreholes. An exceedance is defined as a result above the compliance limit or control level for 3 consecutive sampling events.

In 2019 there was a continued exceedance of the compliance limit and control level for Molybdenum at borehole E05-03, however the upward trend observed since 2012 seems to have plateaued somewhat in 2017 to 2019 with results fluctuating between 1160 and 1610ug/l, this may be as a result of the mitigating actions carried out in 2015 or the ground water reaching an equilibrium with the source. There was also elevated Molybdenum levels in borehole E06/02 in Q2 & 3 2019, interestingly the Molybdenum results mirror the Chloride results for Q2 & 3 suggesting a possible linkage, this will be monitored in future years. Cadmium results were not elevated in borehole E05/03 in Q3 2019 as in previous years, results do not seem to follow a trend and therefore further monitoring is required (Note – Cadmium is no longer regarded as a hazardous substance in groundwater).

Figure 4 shows the control chart for molybdenum for E05-03 and the two other boreholes closest to it, E05-04 and E06-01 as well as the surface water monitoring points (note there are no surface water compliance limits or control levels for molybdenum). The boreholes are located to the west of and adjacent to Phase 1 and are downgradient of active filling operations. Natural background concentrations of molybdenum in the Porthkerry Formation are <3μg/l and the average pre-filling concentration for the cement works lagoon (SW12) is 3μg/l.

Figure 4: Molybdenum concentrations

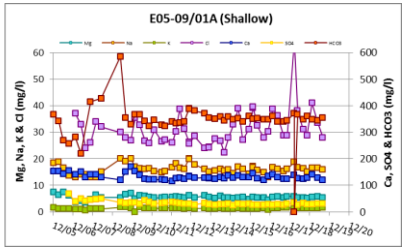


Molybdenum concentrations in E05-03 have been increasing since January 2012, around a year after Phase 1 was completed, which suggests the source is unlikely to be from the deposited PFA. After reviewing the 2016 data it appeared there was a co-association of increasing concentrations in other indicative PFA leachate parameters; boron, sulphate and ammoniacal-nitrogen, suggesting PFA is the source of contamination. During site investigations in 2014, three possible sources were identified; discharges from the wheel wash pipe into an unlined ditch close to the borehole; surface water discharges of eroded PFA areas around the wheel wash pipe into the unlined ditch; and/or; leakage from adjacent cement works lagoon. In 2015, the wheel wash discharge pipe was re-routed into Settlement Pond 1, the unlined ditch cleaned out and the eroded areas smoothed. Since the improvements, molybdenum concentrations continued to increase for over 14 months/5 sampling rounds) until Q1 2017 when the results decreased for two sampling rounds, increased for Q3 and then decreased again for Q4 which suggests levels have plateaued, also this trend appeared to be followed by Boron, Ammoniacal Nitrogen and Sulphate which are the other indicative PFA leachate species, lending weight to the hypothesis that the remedial works in 2015 have mitigated the contamination. These levels have remained stable throughout 2019 in borehole E05/03.

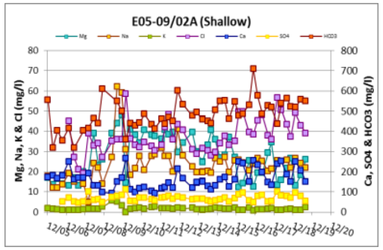
In borehole E05-04, molybdenum concentrations were approximately double the natural background concentrations until March 2014. Since then concentrations have increased moderately up to 59µg/l in Feb 2017and they have fluctuated between 31 and 56µg/l during 2019 . Prior to 2015, the molybdenum concentrations in E06-01 have consistently reflected the natural background concentrations, since February 2015, results have been sporadically above the natural background concentrations up to 67µg/l, but levels have decreased back to historic levels in 2017 to 2019, thus suggesting the source of contamination has not impacted this borehole. There is no co-association of increasing concentrations in other indicative PFA leachate parameters in either E05-04 or E06-01. As in E05-03, molybdenum concentrations in the settlement ponds (SP) have been increasing since January 2012, however, since 2013, concentrations are characterised by large amplitude seasonal fluctuations, with the highest concentrations in the summer and the lowest in the winter. This seasonal fluctuation is reflected in DP2 which collects surface water and groundwater from the site, suggesting the source of contamination is intermittent. The water from the settlement ponds is discharged periodically into the cement works lagoon (SW12) and molybdenum concentrations have been rising steadily since January 2012 to levels similar to those in E05-03.

Figure 2: General Groundwater Quality Charts

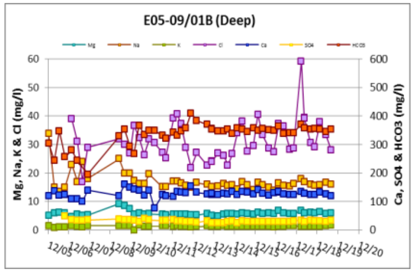
Upgradient Boreholes



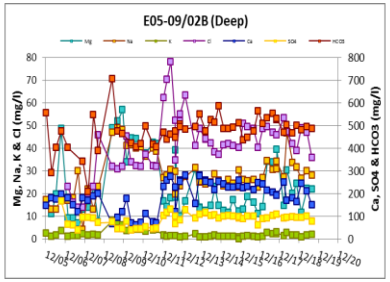
All analytes low and concentrations steady

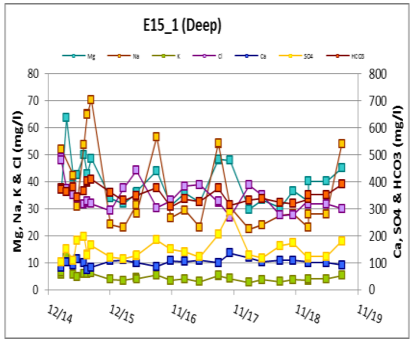


All analytes low but fluctuating, spike Mg 09-11

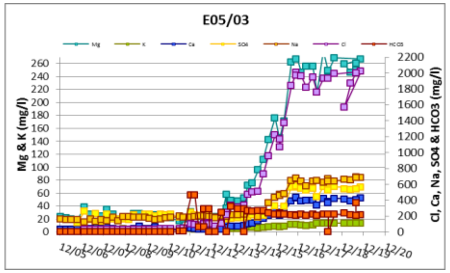


All analytes low, Mg Na higher

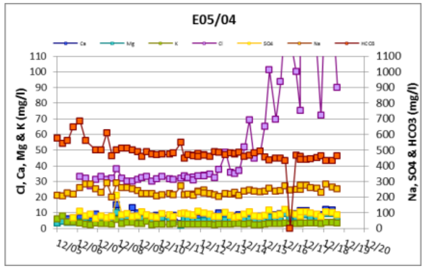




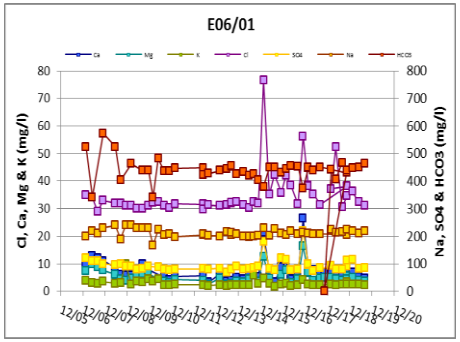
Downgradient Boreholes Phase 1/2



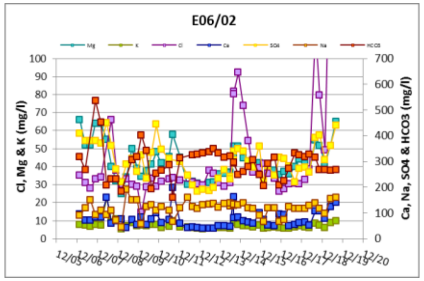
All analytes low, concentrations steady, Ca depleted, Cl increasing Feb-15



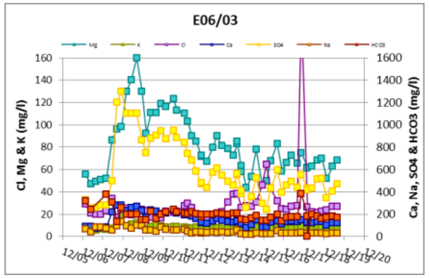
All analytes low, concentrations steady, Ca depleted



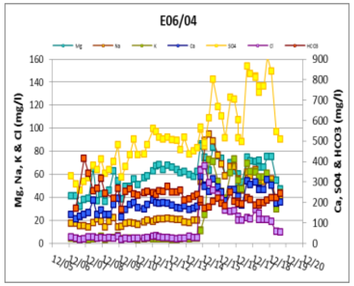
Downgradient Boreholes Phase 3/4



All analytes low except Mg and SO4 elevated, Cl increasing from Mar-14



Downgradient Boreholes Future Phase



All analytes low except SO4 increasing

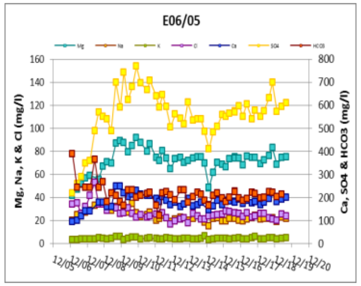


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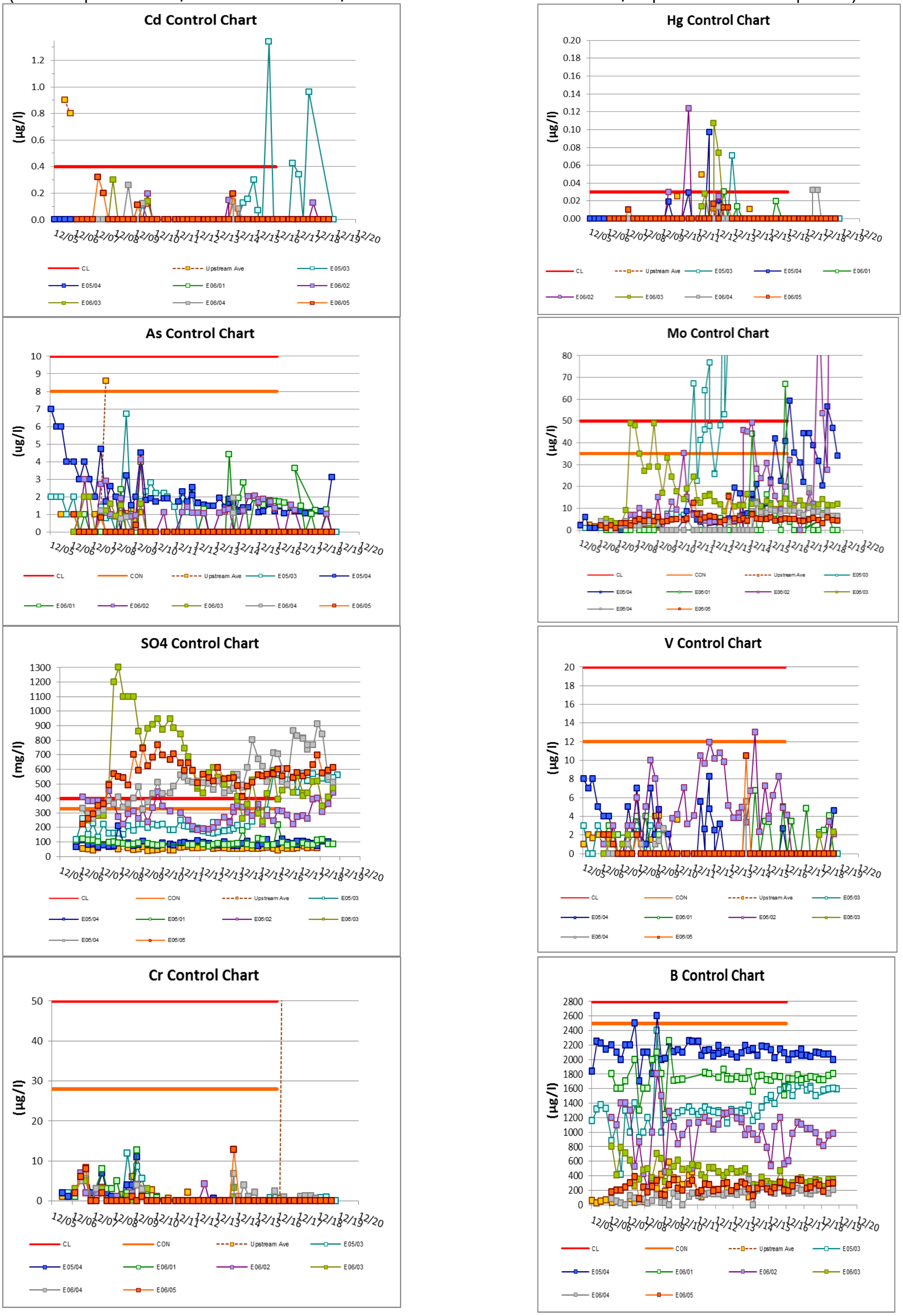
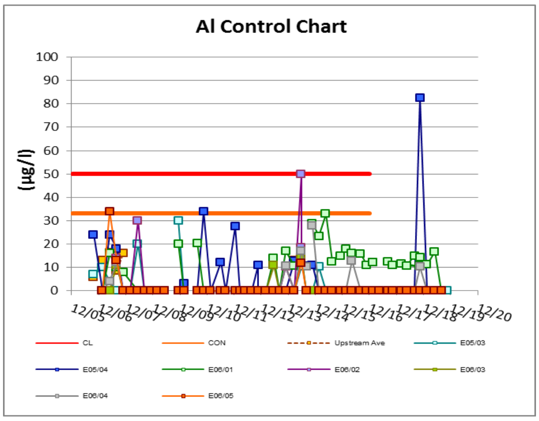
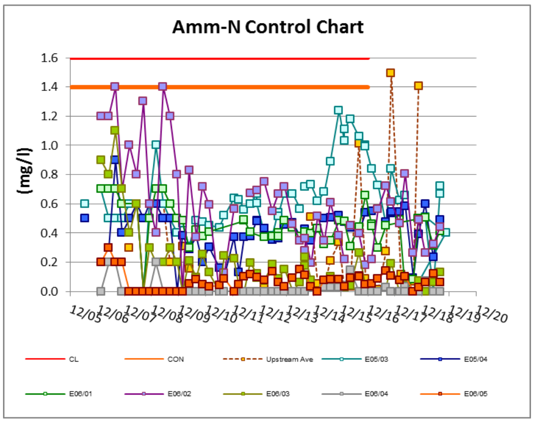
Figure 3: Control charts for groundwater boreholes

(CL – Compliance Limit, CON – Control Level, 0 – result at Method Detection Limit, Duplicate results also plotted)







A summary of the average groundwater quality for all monitoring parameters between 2006 and 2019 is provided in Appendix B with a comparison of pre- and post-fill concentrations. The key trends in the data have been discussed above, however, it can be summarised that there may be some low level contamination from fugitive emissions of PFA, which is considered to have not significantly impacted the groundwater receptors.

The difference in pH between field and laboratory measurements in 2019 was less than 0.5 pH units. Electrical Conductivity shows a significant sampling effect, for Q1-3 all the laboratory measurements were greater than field measurements while the majority of Q4 results were the opposite. Samples from borehole E05-03 for Q3&4 appear to be in error since there is nearly an order of magnitude difference between the laboratory measurement (6400,6300µS/cm) and the field measurement (890,1075µS/cm) A change greater than +10% may indicate a change in sample conditions and therefore for some samples precipitation of solids between sampling and analysis may be occurring. Major ion balances were all within +/- 5% except for E06-03 which was 6% suggesting precipitation of solids is minimal. Duplicate samples collected during 2019 showed good repeatability and were within the expected laboratory error of +/- 20%.

2.3. Surface Water Quality Review

Monitoring Objective

To carry out routine monitoring of surface water to;

- monitor the performance of the ash disposal site by measurement of absolute levels and concentrations and trends relative to relevant criteria including background concentrations and control levels; and;
- identify and quantify effects on surface water receptors.

Number and Location of Monitoring Points

A summary of the surface water monitoring points is provided in Table 3 below and the locations are shown in Appendix A. As detailed in a letter to NRW dated 13thJune 2014 a new surface water monitoring point has been added, DP2, to monitor the composition of water from the under-drainage. Routine monitoring at DP2 began in May 2014.

Table 3: Summary of Surface water monitoring points

Monitoring Point	Description	Direction from site	Designation
SW12	East shore of cement works lagoon in NW area	West	Surface water Receptor
Settlement Ponds (SP)	Two concrete ponds collecting groundwater and surface water	South-west	
DP2	Surface water and groundwater drainage channel at base of Phase 1 and 2	West within site	

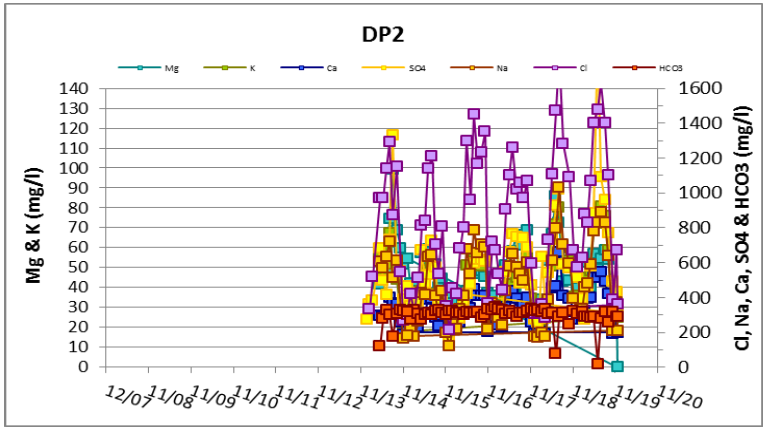
A large proportion of the upstream and underlying groundwater will be collected in the groundwater drainage layer and directed towards the two settlement ponds along with any water that has infiltrated through the PFA and the barrier/attenuation layer. Surface water from runoff is also directed into the two settlement ponds via a series of perimeter ditches and toe drains. The settlement ponds are constructed on the quarry floor, contained by concrete and butyl lined 3m high bunds and are designed to allow suspended solids to settle out before the water is discharged through penstocks into the nearby cement works lagoon (SW12). Periodically these ponds are drained and the solids removed and deposited back into the quarry.

Monitoring Measurements

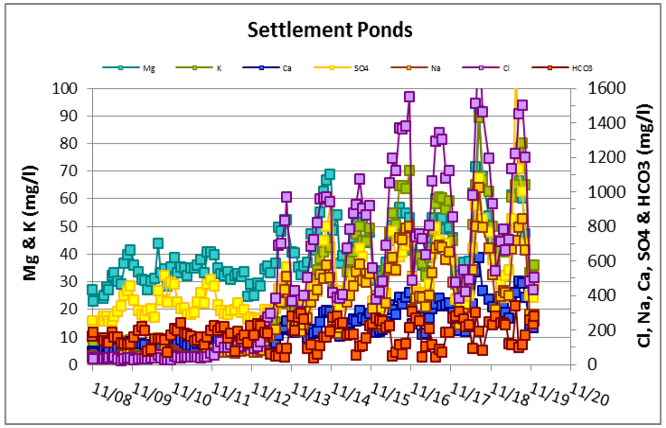
The surface water monitoring analytical suite contains a range of parameters which are monitored on a quarterly basis for SW12 and a monthly basis for the SP and DP2, in accordance with the Environmental Permit. Trained in-house operatives are responsible for the sampling of the SP and DP2 and an independent external contractor is responsible for the sampling of SW12. An independent external laboratory is responsible for the analysis of the samples. There was a change to the analytical laboratory from September 2009 for the SP surface water analysis and from Q2 2010 for the SW12 surface water analysis.

Figure 5 shows the general surface water quality for the major ions. Calcium, magnesium and sulphate concentrations appear naturally elevated in the cement works lagoon and the settlement ponds i.e. prior to any PFA deposition, and are at similar concentrations to those in the downgradient boreholes, E06-03, E06-04 and E06-05, suggesting a natural geological or quarry-related source upgradient of this area. Concentrations appear to be seasonably variable in the settlement ponds and the cement works lagoon with highs in July to December and lows in February to June except for HCO3 with lows in July to December and highs in February to June. When routine monitoring began in DP2 in May 2014 this seasonal pattern in concentrations was also evident. The seasonal pattern is much more marked in 2013-2019 with much higher chloride concentrations than seen previously, which could be due to the use of sea water for ash conditioning during the drier months.

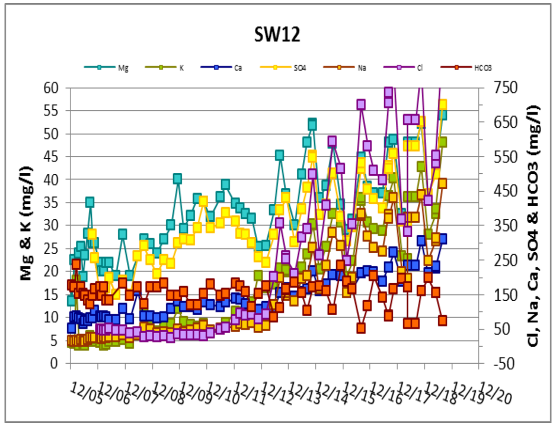
Figure 5: General Surface Water Quality Charts



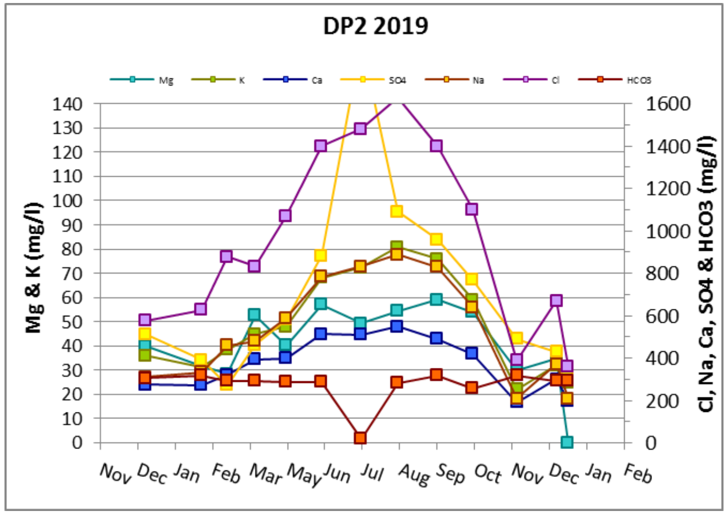
Fluctuations in SO4, Na & Cl with high concentrations in summer and low concentrations in winter.



From 2013 fluctuations in Mg, K, Ca, SO4, Na & Cl with high concentrations in summer and low concentrations in winter and HCO3 with low concentrations in summer and high concentrations in winter.



From 2013 fluctuations in Mg, K, SO4, Na & Cl with high concentrations in summer and low concentrations in winter.



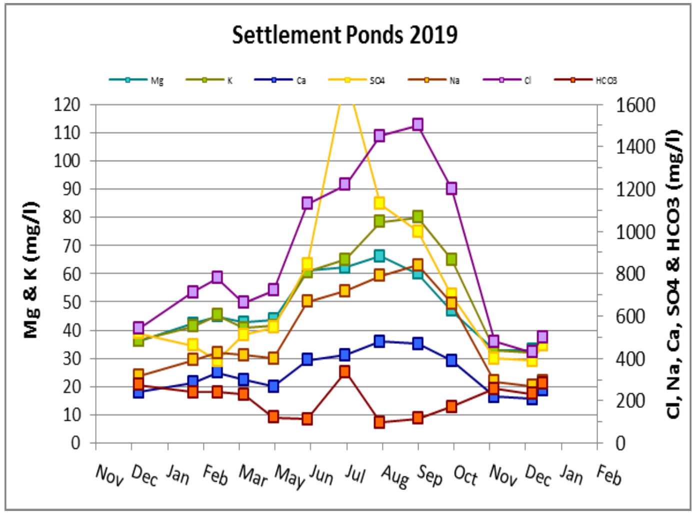


Figure 6 shows the surface water control charts. It should be noted that the compliance limits apply to the discharge from the settlement ponds whilst the control levels (where defined) apply to both the discharge from the settlement ponds and SW12. An exceedance is defined as a result above the compliance limit or control level for 3 consecutive sampling events.

In 2018, there were no exceedances of the compliance limit or control level for any critical parameter, except for sulphate and ammoniacal nitrogen. SP sulphate concentrations exceeded the compliance limit of 400mg/l for Febuary, October and November. A temporary approval of the elevated discharge is in place with NRW on the basis of no environmental impact and the understanding that the elevated concentrations are being caused by drainage into the site from the south-east. This has also been suggested by the HRA conducted in 2018. SP Ammoniacal nitrogen concentrations exceeded the compliance limit of 0.6mg/l in each month apart from April although sufficient oxidation or stripping appears to take place by the time the discharge passes to the cement works lagoon as concentrations are low and not increasing. Ammonia is injected into the Power Station flue gas stream to increase the efficiency of the Electrostatic Precipitators, this will result in the Ash being slightly Ammoniated. This is likely to be the source of the elevated Ammonia levels observed at DP2.

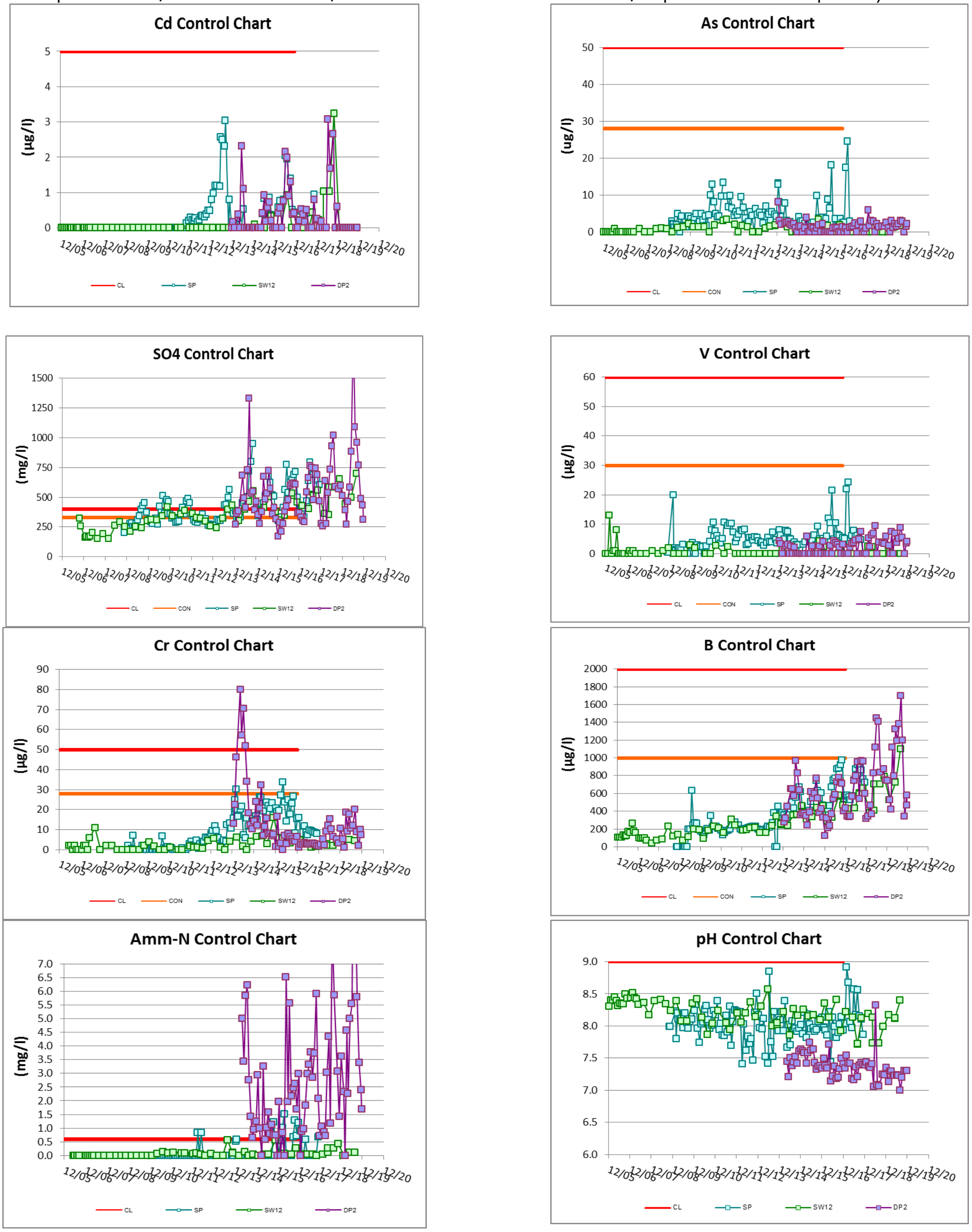
In general, Figure 6 shows that there are no increasing trends in critical parameter concentrations except for sulphate as discussed above and that although concentrations of critical parameters have been variable over time there appears to be no impact on the water quality within the cement works lagoon, SW12 into which the settlement ponds discharge.

During 2015, works to improve surface water management included the re-profiling of drainage ditches, concrete lining of some of the key surface water ditches and removal of small PFA slippages.

A summary of the average surface water quality between 2006 and 2019 is provided in Appendix B with a comparison of pre- and post-fill concentrations. The key trends in the data have been discussed above, however, it can be summarised that there may be some low level contamination from fugitive emissions of PFA, which is considered to have not significantly impacted the surface water receptors.

Figure 6: Surface Water Control Charts

(CL – Compliance Limit, CON – Control Level, 0 – result at Method Detection Limit, Duplicate results also plotted)



3. Annual Production/Treatment Data

Table 5: Annual Production/Treatment Data(Table S5.2 EP)

Parameter	Value	Unit
Surface water disposed off site	0	m^3/yr
Groundwater disposed off site	0	m^3/yr

4. Contamination/Decontamination of Site

There have been no incidents or emissions which may have caused any site contamination during 2019, and, therefore, no requirement to decontaminate the site during 2019.

5. Topographical Survey

The last topographical survey to ordnance datum was carried out in July 2018 which is shown in Appendix C.

6. Landfill Capacity

Table 6 below details the amount of PFA deposited at Aberthaw Quarry Ash Disposal Site during 2018 as reported to Natural Resources Wales via the Waste Return Form. The total amount deposited is well below the permitted annual waste input limit of 650,000 tonnes, and reflects the greatly reduced operation of the Power Station. It is estimated that around 2,478,843m^3 of void capacity remains (Phases 1–4).

Table 6: PFA Deposited

Reporting Period	PFA Deposited (tonnes)
1st January – 31st December 2019	1,568

7. Waste Acceptance Compliance Testing

Aberthaw Quarry Ash Disposal Site is a mono-landfill site which is under the direct operational control of Aberthaw Power Station. All the ash is transported directly from the Power Station using lorries.

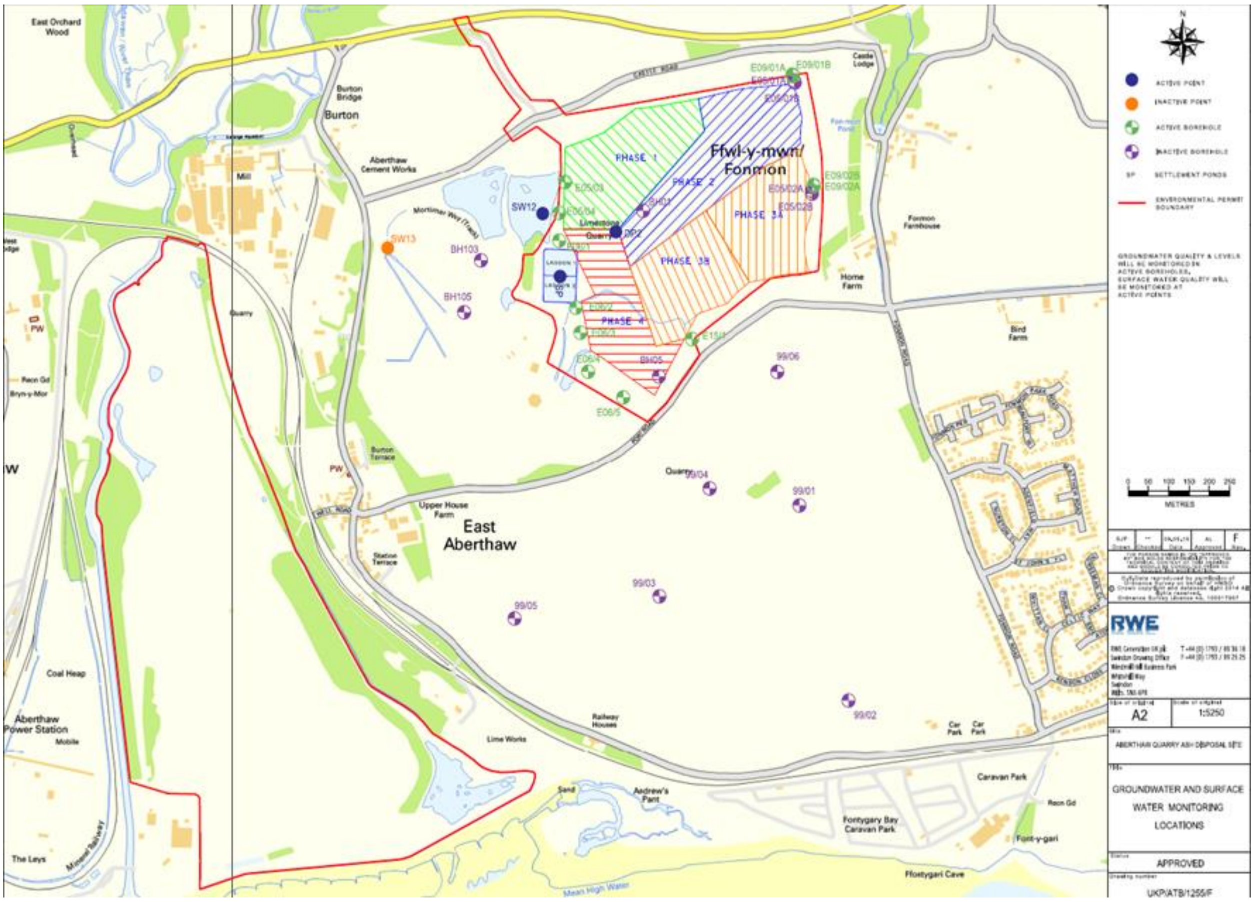
The exact composition of PFA is dependent upon the composition of the fuel utilised by Aberthaw Power Station. RWE has well established procedures which control the quality of fuel supplied to its stations.

Table 7 summarises the analytical data obtained for leachate tests performed on composite samples of conditioned PFA from Aberthaw Power Station between 2012 and 2018. The CEN two-stage method for leachate analysis was used (BS EN 12457-3:2002 Characterisation of waste – Leaching – Compliance test for leaching of granular waste materials and sludge's of which Part 3).

Table 7: Summary of 10:1 Leachate Calculated Results (mg/kg)

Period	Jan-17	Apr-12 to Jan-17			
Analyte:	Latest Result	Minimum	Mean	Maximum	Number of results
Aluminium as Al (Dissolved)	8.1	2.4	21.9	75.4	15
Ammoniacal Nitrogen as N	156.6	4.2	83.5	158.1	15
Antimony as Sb (Dissolved)	0.192	0.020	0.163	0.256	15
Arsenic as As (Dissolved)	2.449	0.077	1.907	3.313	15
Barium as Ba (Dissolved)	1.4	0.1	2.5	5.9	15
Boron as B (Dissolved)	12.1	0.7	12.8	17.7	15
Bromide as Br	36.3	0.6	71.5	293.5	15
Cadmium as Cd (Dissolved)	0.0010	0.0004	0.002	0.0056	15
Chromium as Cr (Dissolved)	0.19	0.01	0.3	1.03	15
Copper as Cu (Dissolved)	0.010	0.004	0.015	0.028	15
Cyanide (Total) as CN	0.5	0.2	0.3	0.5	15
Dissolved Organic Carbon	25.5	2.2	22.6	43.3	15
Fluoride as F	21.7	2.3	23.5	45.1	15
Iron as Fe (Dissolved)	1.16	0.52	1.03	1.52	15
Lead as Pb (Dissolved)	0.043	0.013	0.034	0.083	15
Manganese as Mn (Dissolved)	0.025	0.006	0.066	0.174	15
Mercury as Hg (Dissolved)	0.0019	0.0004	0.0057	0.0132	15
Molybdenum as Mo (Dissolved)	8.1	0.7	9.4	17.8	15
Nickel as Ni (Dissolved)	0.040	0.003	0.028	0.062	15
Nitrate as N	4.6	2.3	3.1	4.6	15
Selenium as Se (Dissolved)	2.8	0.2	2.1	3.5	15
Sodium as Na (Dissolved)	327	9	821	2696	15
Total Dissolved Solids	6787	350	8888	21800	15
Total Nitrogen as N	162.7	5.0	92.1	166.0	15
Total Sulphur as SO4 (Dissolved)	3745	170	3422	4271	15
Vanadium as V (Dissolved)	3.59	0.40	2.39	3.59	15
Zinc as Zn (Dissolved)	0.17	0.01	0.14	0.57	15

Appendix A. Groundwater and Surface Water Monitoring Locations



Appendix B. Groundwater and Surface Water Quality

(Dark orange exceeds compliance limits, light orange exceeds EQS/DWS, blue exceeds background >25%)

	Aquifer	Response Zone Interval[1]	Al		Sb		As		B		Cd		Ca		Cr		Cu		Fe	
		m b GL	µg/l		µg/l		µg/l		µg/l		µg/l		mg/l		µg/l		µg/l		µg/l	
Background - Limestone			11		3		2		201		0.6		153		9		6		147	
Background - Seawater			256		<10		2		4166		0.1				1		12		<100	
GW EQS/DWL			200		5		10		2000		5.0		250		50		2000		200	
GW MRV							1				1.0									
GW CL			**50**				**10**		**2800**		**0.4**				**50**					
SW CL							**50**		**2000**		**5.0**				**50**					
Upstream Groundwater			**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**	
E05-09_01A	Limestone	18-24	14		3		1		43		#DIV/0!		133		3		3		106	
E05-09_01B	Limestone	24-30	16		1		1		42		#DIV/0!		128		3		2		92	
E05-09_02A	Limestone	21-27	12		3		1		121		0.1		163		3		5		398	
E05-09_02B	Limestone	27-33	64		2		2		303		0.5		193		4		6		316	
E15_1	Limestone	17-29	21		#DIV/0!		#DIV/0!		221		#DIV/0!		100		3		1		64	
Downstream Active Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E05_03	Limestone	3-15	15	11	4	1	1	1	1109	1385	#DIV/0!	0.2	37	175	3	1	7	2	38	45
E05_04	Limestone	2.5-20	21	11	6	2	4	2	2123	2122	#DIV/0!	#DIV/0!	6	8	4	1	5	1	39	31
E06_01	Limestone	3-15	16	14	6	1	1	1	1667	1753	#DIV/0!	#DIV/0!	10	7	4	1	1	1	47	30
E06_02	Limestone	2-10	21	11	6	1	2	1	1113	983	#DIV/0!	0.1	89	73	3	1	5	1	86	30
Downstream Future Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E06_03	Limestone	2-10	19	10	5	2	1	1	561	408	#DIV/0!	0.1	131	155	3	1	2	2	71	#DIV/0!
E06_04	Limestone	2-10	17	11	4	1	1	1	58	162	#DIV/0!	0.1	147	223	3	1	5	3	55	36
E06_05	Limestone	2-8	21	10	5	1	1	1	224	243	0.4	0.1	129	188	3	1	2	2	33	#DIV/0!
Downstream Surface Water			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
DP2 Phase 2 West				13		1		2		641		0.4		325		13		3		#DIV/0!
Settlement Ponds				90		1		5		296		0.3		155		8		2		55
SW12 Lafarge Lagoon			21	11	5	1	1	1	122	375	#DIV/0!	0.2	86	170	2	3	2	2	32	30

	Aquifer	Response Zone Interval[1]	Mg		Mn		Hg		Mo		Ni		K		Se		Na		V	
		m b GL	mg/l		µg/l		µg/l		µg/l		µg/l		mg/l		µg/l		mg/l		µg/l	
Background - Limestone			16		47		0.02		3		4		5		3		21		2	
Background - Seawater					<20		0.02		<30		9		380		<1				<20	
GW EQS/DWL			50		50		1.00		70		20		12		10		200		60	
GW MRV							0.10													
GW CL							**0.03**		**50**										**20**	
SW CL																			**60**	
Upstream Groundwater			**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**	
E05-09_01A	Limestone	18-24	6		12		0.01		1		3		1		2		16		2	
E05-09_01B	Limestone	24-30	6		8		0.02		3		3		1		3		17		2	
E05-09_02A	Limestone	21-27	27		66		0.01		3		4		2		3		24		2	
E05-09_02B	Limestone	27-33	23		51		0.01		2		5		2		2		28		2	
E15/1	Limestone	17-29	40		25		#DIV/0!		9		2		5		2		39		#DIV/0!	
Downstream Active Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E05_03	Limestone	3-15	24	114	11	39	#DIV/0!	0.01	1	553	2	2	4	7	1	1	149	357	2	2
E05_04	Limestone	2.5-20	4	6	6	9	#DIV/0!	0.01	2	10	2	1	4	3	2	1	241	232	4	3
E06_01	Limestone	3-15	7	5	#DIV/0!	13	#DIV/0!	0.01	1	6	1	1	3	3	1	1	215	212	2	2
E06_02	Limestone	2-10	56	40	18	10	#DIV/0!	0.01	3	30	4	2	10	7	2	1	109	118	2	5
Downstream Future Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E06_03	Limestone	2-10	62	83	10	12	#DIV/0!	0.01	11	17	5	3	7	8	5	2	70	43	1	2
E06_04	Limestone	2-10	42	63	5	23	#DIV/0!	0.01	3	6	4	4	4	27	2	1	17	41	1	2
E06_05	Limestone	2-8	52	74	6	11	0.04	0.01	2	5	4	2	4	5	2	1	27	23	1	2
Downstream Surface Water			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
DP2 Phase 2 West				46		32		0.01		2102		16		40		13		466		3
Settlement Ponds				37		10		0.03		577		9		17		2		179		5
SW12 Lafarge Lagoon			23	38	2	14	0.05	#DIV/0!	3	733	2	4	6	22	2	2	23	196	2	2

	Aquifer	Response Zone Interval[1]	pH		EC		Bicarbonate		Sulphate		Ammoniacal Nitrogen as N		Total Oxidised Nitrogen as N		Nitrate		Chloride		Fluoride		Total Organic Carbon	
		m b GL			µS/cm		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l	
Background - Limestone			7.31		825		412		56		#DIV/0!		11.62		#DIV/0!		35		0.4		#DIV/0!	
Background - Seawater			7.88				97		2396								16300		1.3			
GW EQS/DWL			8.50		2500		250		400		0.3				50		250		1.5			
GW MRV																						
GW CL									**400**		**1.6**											
SW CL			**9.00**						**400**		**0.6**											
Upstream Groundwater			**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**		**Average**	
E05-09_01A	Limestone	18-24	7.39		677		344		33		0.03		5.69		52		31		0.1		4	
E05-09_01B		24-30	7.39		668		337		32		0.04		5.14		24		31		0.1		3	
E05-09_02A		21-27	7.27		913		484		68		0.90		12.00		7		37		0.2		4	
E05-09_02B		27-33	7.23		1055		475		88		0.13		24.38		21		42		0.2		6	
E15/1		17-29	7.52		832		355		149		0.25		3.01		2		35		0.2		2	
Downstream Active Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E05_03	Limestone	3-15	8.50	7.69	977	3044	#REF!	#REF!	178	307	0.53	0.64	0.14	0.81	0.42	1.08	33	773	1.4	1.4	16	3
E05_04		2.5-20	8.79	8.54	1010	948	564	474	79	91	0.53	0.40	0.30	0.07	0.84	#DIV/0!	31	44	6.4	5.2	19	5
E06_01		3-15	8.66	8.60	923	877	473	426	106	92	0.58	0.43	0.45	0.25	#DIV/0!	0	33	35	2.1	2.9	19	2
E06_02		2-10	8.39	7.81	1214	1041	336	287	390	287	1.09	0.50	0.72	0.59	0.60	0.46	38	48	0.6	0.5	5	4
Downstream Future Filling Operations			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
E06_03	Limestone	2-10	8.20	7.71	1224	1276	276	187	443	603	0.67	0.11	2.28	0.74	1.60	0.08	23	30	0.5	0.4	4	4
E06_04		2-10	7.99	7.57	930	1463	290	224	320	565	0.20	0.04	0.10	0.95	0.50	0.91	26	101	#DIV/0!	0.3	12	15
E06_05		2-8	8.08	7.57	1063	1243	289	205	363	583	0.21	0.07	0.30	0.16	3.30	-0.36	37	25	#DIV/0!	0.4	9	1
Downstream Surface Water			**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**	**Prefill**	**Postfill**
DP2 Phase 2 West				7.37		3749		297		543		2.76		24.67		22.36		837		0.2		1
Settlement Ponds				8.01		1701		165		380		0.10		6.55		11.63		300		0.3		2
SW12 Lafarge Lagoon			8.38	8.13	713	1844	159	147	207	405	#DIV/0!	0.10	1.16	4.42	5.09	1.69	44	322	#DIV/0!	0.2	8	3

Appendix C. Topographical Survey