1.0 Traffic

1.1 WSCC traffic data

The table below uses the traffic data collected for Balcombe PC in 1999[6] and 2006. Figures are 10000 vehicles a day with 4000 of those using London Road. This report assumes an average HGV percentage of 5%, although this may be lower or higher it would be standard practice to assume a 5.4% volume on this type of road.

These flows are average and vary through the day. The greatest flows are in the morning peak with some 400 vehicles an hour past the school.

1.2 Exploration – Vehicle Movements

The following table summarises the vehicle movements for the stages of the exploration granted planning permission. They are taken from the traffic report submitted to WSCC as part of the exploration planning application.

WSCC planning application Appendix F [5]							
Activity	**Duration**	**Cuadrilla Planning Application**		**WSCC Daily Flows 1999**		% increase	
		HGV	**Light vehicles**	**HGV** as 5% volume	**Traffic flow London Road**	HGV	Light
		(movements/day)		(movements/day)			
Refurbishment of drilling site	2 weeks	6	4	200	4000	3	0.1
Erection of drilling rig	4 days	20	30	200	4000	10	0.8
Drilling (first week)	5 days	30	30	200	4000	15	0.8
Drilling (remainder)	2 to 4 weeks	0 to 10	30	200	4000	5	0.8
Removal of the drilling rig	4 days	20	30	200	4000	10	0.8
Testing	2 to 4 weeks	4	2	200	4000	2	.05

Combined tables section 3.0 and 4.14

1.3 Extraction – Vehicle Movements

Figures giving a guide to vehicle movements for the extraction period are available from several sources. I have used the data put forward in the Tyndall report[2], The Institute of Energy at Texas University[3], the IGEM Shale Gas Report [4] and estimates from Cuadrilla.

The Micrite layer at the Balcombe site is approx 150ft deep[5]. Water consumption is likely therefore to be less than some of the figures reported in sources listed which will be into seams of greater width and therefore fracked to a greater depth.

1.4 Independent Sources

The values below are taken from the **Tyndall Report[2]**, as revised in December 2011.

Table 2.6: Truck visits over lifetime of six well pad				
Purpose	**Per well**		**Per pad**	
	Low	**High**	**Low**	**High**
Drill pad and road construction equipment			10	45
Drilling rig			30	30
Drilling fluid and materials	25	50	150	300
Drilling equipment (casing, drill pipe, etc.)	25	50	150	300
Completion rig			15	15
Completion fluid and materials	10	20	60	120
Completion equipment (pipe, wellhead)	5	5	30	30
Hydraulic fracture equipment (pump trucks, tanks)			150	200
Hydraulic fracture water	400	600	2,400	3,600
Hydraulic fracture sand	20	25	120	150
Flow back water removal	200	300	1,200	1,800
Total			**4,315**	**6,590**
...of which associated with fracturing process:			***3,870***	***5,750***
			90%	***87%***

[5]Tyndall Report Rev Dec 2011

Table 2.7: Summary of resources, no refracturing scenario			
	Activity	**Six well pad drilled vertically to 2000m and laterally to 1,200m**	
		Low	**High**
Construction	Well pad area (ha)	1.5	2
Drilling	Wells	6	
	Cuttings volume (m3)	827	
Hydraulic Fracturing	Water volume (m3)	54,000	174,000
	Flowback fluid volume (m3)	7,920	137,280
Surface Activity	Total duration of surface activities pre production (days)	500	1,500
	Total truck visits	4,315	6,590

[5]Tyndall Report Rev Dec 2011

1.5 Balcombe Estimates

Movements relate to the fracking operation itself, removal of extracted oil over the period of the well or wells and associated light traffic for personnel.

Wells may be drilled and fracked over a number of years to keep production steady. Initial activity for a single well is likely to take place over about 6 weeks

Estimates of water usage and Tanker Movements at Balcombe Well								
Single Frack								
	Source							
Purpose	Tyndall[5]		Cuadrilla		IGEM[4]		IEUTA[3]	
	Low	High	Low	High	Low	High	Low	High
Water			500 cu m	1000 cu m			0.5M US gallons	0.76 M US gallons
			0.5 Ml	1 Ml	1 Ml	3.6 Ml	2Ml	3Ml
(tankers)	90	120	40	80	45	144	76	116
Flow back								
(tankers)								
Oil			*unknown*					
(tankers)			*unknown*					
Personnel								
(light vehicles)								
Total	108	138						
Single Well (multiple frack) (over 6 week period)								
	Source							
Purpose	Tyndall[5]		Cuadrilla		IGEM[4]		IEUTA[3]	
	Low	High	Low	High	Low	High	Low	High
Water			5000 cu m	7500 cu m			4 M US gallons	6.1 M US gallons
	9 Ml	29 Ml	5 Ml	7.5Ml	9 Ml	29 Ml	15 Ml	23 Ml
(tankers)	650	966	200	350	360	1160	606	924
Flow back								
(tankers)								
Oil								
(tankers)								
Personnel								
(light vehicles)								
Total	716	1100						

6 Well Pad (multiple frack) (over 36 week period, not necessarily concurrent)								
	Source							
Purpose	Tyndall[5]		Cuadrilla		IGEM[4]		IEUTA[3]	
	Low	High	Low	High	Low	High	Low	High
Water			30000 cu m	45000 cu m			24 M US gallons	36.6 M US gallons
	54 Ml	174 Ml	30 Ml	45 Ml	54 Ml	174 Ml	91 Ml	138 Ml
(tankers)	3900	5800	1200	1800	2160	3960	3636	5545
Flow back								
(tankers)								
Oil								
(tankers)								
Personnel								
(light vehicles)								
Total	4300	6600						

Red denotes extrapolation/ calculation. Assumes tanker volume of about 25,000 litres or 25 cu m. This may be less for rural roads. Assumes single well is fracked 8 times relative to exploration stage.

1.6 Relative Water Volumes

- The capacity of Ardingly Reservoir is 5200 M litres.[11]
- Southeast Water[12] supply 565M litres a day to its customers, Southern Water [11] about the same at 600M litres.
- Both companies lose about 90M litres a day through leakage.
- An Olympic swimming pool holds 2.5M litres

Using Cuadrilla's figures;
A single exploratory well would use, 0.02% of the reservoir, 0.2% of daily supply, 1% of leakage, half an Olympic swimming pool/
A single well (8 frack), 0.16% of reservoir, 1.3% of daily supply, 8% of leakage, 3 olympic swimming pools.

Domestic Usage

Daily consumption stands at about 150 litres per person daily. For the population of Balcombe that means about 270,000 litres a day. Plus about another 12% 10 for our main business, agriculture, is about 300,000 litres supply a day.

Using Cudrilla's figures;
A single exploratory frack would be 3 days worth of village supply.
A single well (8 fracks) 25 days.

Whilst these figures are not insignificant it is worth considering that this could produce oil for a considerable number of years.

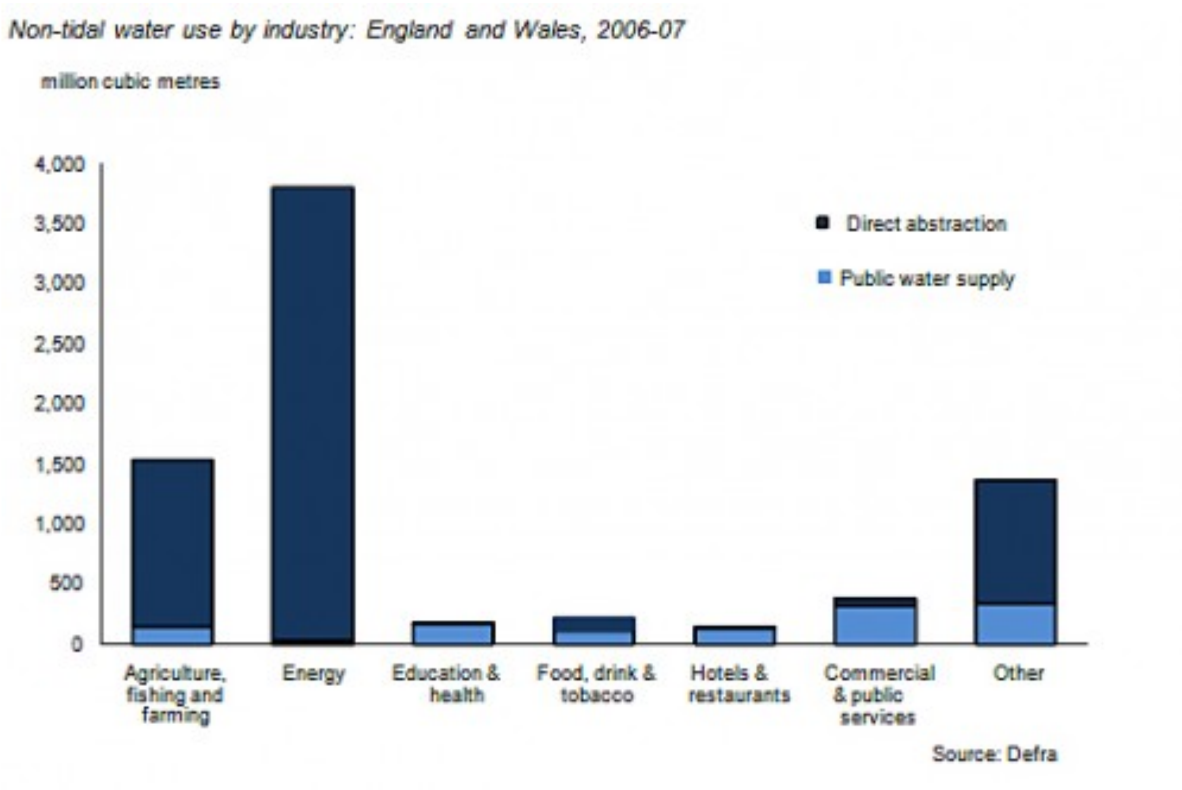
Comparative Industrial usage

Other industrial uses are much larger than domestic consumption.

Defra [10] Publish Water usage statistic for various industries.
http://www.defra.gov.uk/statistics/environment/green-economy/scptb10-wateruse/

Of business usage of 6.3 billion cu meters used annually Electricity supply is the largest user

"Of 33.6 billion litres per day abstracted from non-tidal surfacewater and groundwater in 2008, 47 per cent was for the public water supply and 34 per cent for the electricity supply industry. The electricity supply industry also consumed an estimated 18.7 billion litres per day of tidal water" – Defra [10]



Extract from Defra [10] Website

2.0 Flowback

2.1 General

During Fracking water is introduced to the well. Contained within this are chemicals added to ease the flow and hydraulic operation. Sand is added to act as a propant and to hold open the fissures created, which otherwise would reclose once the water pressure is released.

Once the fissures have been opened and propped the pressure is decreased and between 20 and 80% of the fracking water flows back [3](flowback) to the surface. Along with the introduced water any water found at the depth of fracking is also displaced back to the surface (produced water).

During the operation the fracking fluid itself is likely to have picked up particles and substances. Frack fluid will pick up more the longer it is in the well but this is also dependant on the type of rock encountered. Typically minerals are dissolved into the frack fluid and some of these are what is called NORMS (naturally occurring radioactive material). Granite contains high proportions of NORMS making Cornwall the most radioactive county in the UK !

Produced water is likely to have higher concentrations of soluble and particulate matter as it has had many thousands of years to dissolve these.

It should be noted that produced water would have occurred with the well bore undertaken in 1986 as it is not a result of the fracking process exclusively but would also result with a conventional vertical well.

The water returning to the surface is therefore a mixture of introduced fracking fluid, ancient produced water and any soluble and particulate matter dissolved or picked up during the process. The make up of flowback therefore depends largely on the individual geology of each well site. For this reason it is difficult to predict what the composition of the flow back will be.

2.2 US and Lancashire – Flowback Composition

As explained above the make up of flowback depends largely on the individual geology of each well site. For this reason it is difficult to predict what the composition of the flow back at the Balcombe site will be.

Extensive information is available for flowback in the US but due to the many and vast geographical and geological spread of wells in the US the data varies considerably. It would be better for the reader to follow their own research of data rather than reproduce it here.

In the UK the Environment Agency is monitoring the flowback composition[8 & 9] for Cuadrilla's operations in Lancashire. Summaries and a fairly detailed analysis of the flow back water from Cuadrillas Lancashire operation is available on the Environment Agency website. (copies attached as Appendix A at end of this document). This shows concentrations of heavy metals, salts and other metals /minerals it also shows the presence of NORMS. The results are contrasted with sea water and the local drinking water.

General EA Fracking Page ; http://www.environment-agency.gov.uk/business/topics/134511.aspx

Lancashire Flow back Analysis 3rd Nov 2011 ; http://www.environment-agency.gov.uk/static/documents/Business/Flow_back_water_analysis_011111.pdf

Lancashire Flow back Analysis 6th Dec 2011 ; http://www.environment-agency.gov.uk/static/documents/Business/6th_Dec_-_Shale_gas_-_North_West_-_Monitoring_of_flowback_water_-_update_(2).pdf

2.3 How is Flowback regulated and disposed of in the UK ?

Flowback is regulated in the UK by the Environment Agency (EA). Disposal is subject to EA permit. Permits are issued, or not, after analysis of the flowback including analysis of any NORMS present. Whilst it is possible to dispose of flowback by re-injecting at depth, largely putting it back from where it came, the Lancashire operation is using an industrial processing plant at Davy Hulme[9] to deal with the waste. That is...when a permit is applied for and issued.

In addition the flowback can be recycled but this leads to increasingly higher concentrations of the substances in it and can hamper eventual disposal. However, it can reduce vehicle movements. This applies in practical terms to extraction rather than exploration situations.

The current regulations for disposal were revised under Schedule 23 of the Environmental Permitting Regulations 2011 and can be found on the DEFRA website;

http://www.defra.gov.uk/environment/quality/permitting/

These regulations state maximum NORMS levels allowed for disposal of solids, liquids and gasses, and came in at the start of Oct 2011 (April 2012?). The levels allowable for solids is higher than for liquid which in turn is higher than for gasses.

It is fair to say that *"The potential risk from fracturing additives in flowback water is smaller than that of naturally-occurring contaminants such as arsenic or high dissolved solids from produced water mixed with the flowback",* Energy Institute at university of Texas at Austin[3]. Heavy metals are amongst these.

Cuadrilla states that they do not yet have a plan for disposal at Balcombe, but imply that a similar solution would be pursued.

The EA has stated to BPC that it believes *"water quality risks are manageable at the Lower Stumble site near Balcombe"*

As stated previously, there is less likelihood of NORMS being present in the flowback at Lower Stumble as the rock to be fracked is micrite rather than shale.

2.4 Chemicals to be used in Balcombe are;

Percentage Volume	Chemical/ consituent
0.05%	Biocide (if necessary)
0.075 %	Polyacrylamide
0.125%	Hydrochloric Acid
99.75%	Water and sand

The risks associated with these additives is discussed by others/ elsewhere.

2.5 Risks of spillage, aquifer contamination

Double skin tankage on site lining of the site well pad and stringent planning of the transportation are all key to ensuring risks are avoided.

Tank storage is general practice in the UK although the EA has not ruled out the possibility of considering an application for open pit storage it is highly likely it would consider it and then refuse it. The site at Lower Stumble is already lined. Cuadrilla under took this work shortly after it gained planning permission, but before it started drilling in Lancashire. This includes a sump for spillage collection.

Instances of spillage in US account for verified contamination. No instances of contamination by other means have as yet been verified by the authorities or regulatory bodies[3].

2.6 Exploration vs Extraction

Should be much the same for both constituent wise but volume will differ considerably. Fracking of the exploratory well is planned to involve a single frack. The volume required for this is about 1/48th of a full 6 well frack site. Again, volumes are not daily but spread over a period of time.

If the volumes of flowback is about 20 to 80% of the introduced water then

Well Type	Volume	Percentage / volume	Percentage / volume
Exploratory	1M litres	20% / 200,000 litres	80% / 800,000 litres
Single well	7.5M litres	20% / 1.5M litres	80% / 6M litres
6 well pad	45M litres	20 / 9M litres	80% / 36M litres

The waste disposal site at Goddards Green currently treats 26M litres a day. [11]

3.0 References

The Tyndall Centre for Climate Change Research

1 **Shale gas: a provisional assessment of climate change and environmental impacts**
http://www.tyndall.ac.uk/sites/default/files/coop_shale_gas_report_final.pdf

2 **Shale gas: an updated assessment of environmental and climate change impacts**
http://www.tyndall.ac.uk/sites/default/files/coop_shale_gas_report_update_v3.10.pdf

energy institute University of Texas at Austin

3 **Fact-Based Regulation for Environmental Protection in Shale Gas Development**
http://energy.utexas.edu/images/ei_shale_gas_regulation120215.pdf

Institution of Gas Engineers and Managers

4 **Shale Gas A UK energy miracle ?**
http://www.igem.org.uk/media/107958/IGEM-Shale_Gas-A_UK_energy_miracle-September_2011.pdf

West Sussex County Council

5 **Planning Application – BA ----**
http://www.westsussex.gov.uk/living/planning/planning_applications/planning_applications_for_mine.aspx

6 **WSCC Traffic data 1999**

7 **WSCC / Atkins Traffic data 2006**

Environment Agency

8 North West Monitiring of Flow back water 6th December 2011
http://www.environment-agency.gov.uk/static/documents/Business/6th_Dec_-_Shale_gas_-_North_West_-_Monitoring_of_flowback_water_-_update_(2).pdf

9 North West Monitiring of Flow back water 3rd November 2011
http://www.environment-agency.gov.uk/static/documents/Business/Flow_back_water_analysis_011111.pdf

DEFRA

10 www.defra.gov.uk

Water Companies

11 Southern Water www.southernwater.co.uk
12 Southeast Water www.southeastwater.co.uk

Appendix A

Environment Agency Analysis of Flowback

http://www.environment-agency.gov.uk/static/documents/Business/6th_Dec_-_Shale_gas_-_North_West_-_Monitoring_of_flowback_water_-_update_(2).pdf

http://www.environment-agency.gov.uk/static/documents/Business/Flow_back_water_analysis_011111.pdf

Flowback - 06^{th} Dec 2011

06th Dec 2011; Environment Agency Analysis of Flowback

Environment Agency

Shale Gas

North West - Monitoring of Flowback water

6th December 2011

Results

The Bowland Shale rock formation in Lancashire is a potential source of unconventional shale gas and is described by the British Geological Survey in work for the Department of Energy and Climate Change (DECC) as offering the best potential in the UK.

Cuadrilla Resources are licensed by DECC to explore in this area. They have planning permission to drill up to five exploratory wells. They have drilled two and are currently drilling a third. One of these has progressed to hydraulic fracturing - Preese Hall.

Environmental regulation

Our role is to help ensure that the environment is protected from the potential impacts of exploration and this includes ensuring that the disposal of the “flowback” water from the exploratory wells is managed properly.

What is flowback water?

Some of the water that is injected in to the shale rock during hydraulic fracturing returns to the surface through the drilled well. This is often called the “flowback” fluid or flowback water. Typically around a quarter of the water injected will return to the surface over a period of weeks to a few months. This flowback fluid is very saline, and contains minerals dissolved from the rocks as well as small particles of rock.

Because the water has a high mineral content it has to be disposed of carefully, with the appropriate permits granted, where necessary, for the chosen disposal route.

What analysis did we do and what did we find?

We took samples of the flowback fluid and sent them to our own laboratories for analysis.

The substances found are those which we would expect to find coming from shale rock and are naturally occurring. There are notably high levels of sodium, chloride, bromide and iron, as well as higher values of lead, magnesium and zinc compared with the local mains water that is used for injecting into the shale.

Analysis for us by other laboratories showed that they also contained very low levels of naturally occurring radioactive minerals - similar to the levels found in granite rock.

www.environment-agency.gov.uk

Where does the flowback water go?

The flowback water produced until the end of September from the Preese Hall exploration site was stored in double skinned tanks on site. It was then transported to a waste water treatment works at Davyhulme. The fluid is now stored on site.

The waste water treatment works already treats many other industrial effluents from the Manchester area and holds a permit from the Environment Agency to discharge to the Manchester Ship Canal. It is capable of dealing with the levels of minerals contained in the flowback water.

Does Cuadrilla need a permit?

The quantities of minerals present are not sufficient in themselves to require an environmental permit to store and dispose of the flowback water. However, from 1 October 2011, new limits for radioactive materials were specified in Schedule 23 of the Environmental Permitting Regulations 2010. These supersede previous limits. Cuadrilla now need a permit if they want to continue disposing of these fluids to the waste water treatment works because the levels measured combined with the expected quantities of flowback fluid exceed the new limits. We have told them that they need to apply to us for a permit and provide us with more information so we can assess their proposal.

What is happening to the flowback fluid now?

Currently the flowback fluid is being stored in double skinned tanks on site pending a permit application.

Appendix 1 A comparison of the mineralisation of this water with other waters

Different water sources have different levels of these chemicals. Below is a table to give an indication of how the maximum levels in the flowback fluid compare to those in other water sources.

	Sea Water **(grams per litre)**	**The Dead Sea** **(grams per litre)**	**Flowback** Fluid **(grams per litre)**
Sodium	10.1	36.3	34.8
Chloride	19.4	230.4 (for chloride plus bromide)	92.8
Bromide			1.0
Magnesium	1.3	45.9	2.1
Potassium	0.4	7.8	0.1

Appendix 2: Table of Environment Agency dissolved salts sample analysis

Notes to support table

- Mains water with small amounts of additives are injected into the exploratory well - this is the fracking fluid. We include a typical analysis for mains tap water in the Singleton area. (sourced from United Utilities web pages) as a comparison to the analysis of the flowback fluid that returned to the surface..
- The variation between this and the flowback analysis indicates the minerals which have been taken from the shale formation during the fracking process.
- The analysis of the flowback water is reported in either micrograms per litre (µg/l), or milligrams per litre (mg/l). (Note 1 mg/l = 1000 µg/l). Filtered means filtered to remove solids.
- In one sample we also analysed for acrylamide as an impurity arising from the fracking fluid injected into the rock or a possible breakdown product from the polyacrylamide in the fracking fluid. We found very low concentrations in the flowback fluid.

SITE	Cuadrilla Drill Rig	Cuadrilla Drill Rig	Cuadrilla Drill Rig	Cuadrilla Drill Rig	Cuadrilla Drill Rig	Cuadrilla Drill Rig	Cuadrilla Drill Rig	Mains water average concentration
DATE	7 April 2011	14 April 2011	28 April 2011	18 May 2011	14 June 2011	1 Aug 2011	17 Aug 2011	
TIME	13:20	13:30	11:10	14:00	09:55	11:00	09:30	
Conductivity at 25oC µs/cm	–	–	–	150614	133730	176000	_	299
pH	–	–	–	6.35	7.06	6.33	_	7.54
Acrylamide µg/l							0.05	
Lead (filtered) µg/l	179	<20	<2	<40	<40	<20	< 100	
Lead - as Pb µg/l	600	<10	<10	<40	44.9	80.5	< 100	<0.417
Mercury (filtered)	0.01	<0.01	0.013	<0.01	<0.01	<0.01	< .01	

µg/l								
Mercury - Hg µg/l	0.024	<0.01	<0.01	<0.01	0.012	0.09	0.038	<0.013
Cadmium (filtered) µg/l	0.674	<1	1.47	<2	<2	<1	< 5	
Cadmium - Cd µg/l	1.29	<0.5	<0.5	<2	<1	6.02	< 5	<0.04
Bromide mg/l	–	–	242	854	608	673	1020	<0.444
Chloride Ion mg/l	15400	34400	22200	75000	64300	58000	92800	13.5
Sodium (filtered) mg/l	7950	15100	9330	28400	>200	21400	33300	
Sodium - Na mg/l	no bottle	15100	9380	28400	23600	21700	34800	22.9
Potassium (filtered) mg/l	23.2	46.4	37.8	82.1	>20	64.9	90.7	
Potassium - K mg/l	28.8	52.3	40.6	–	–			
Magnesium (filtered) mg/l	177	>50	397	–	–			
Magnesium - Mg mg/l	no bottle	586	401	1470	1350	1370	2170	9.21
Phosphorus - P mg/l	1.28	0.0771	<0.02	<0.1	<0.5	0.532	< 0.2	
Chromium (filtered) µg/l	< 3	<5	0.565	28	<10	<5	40	
Chromium - Cr µg/l	25	4.03	<3	20.5	53.9	222	42.9	<0.349
Zinc – (filtered) µg/l	297	<50	53.6	142	411	107	<300	
Zinc - as Zn µg/l	565	51.5	<30	173	435	382	<300	

Nickel – (filtered) µg/l	13.8	<10	21.5	<20	<20	<50	<50	
Nickel - Ni µg/l	20.3	<5	<5	<20	<20	<20	<50	1.20
Silver (filtered) µg/l	< 10	<5	<10	<20	<10	<1	<50	
Silver µg/l	–	–	<1	<20	<10	<20	99.4	
Aluminium (filtered) µg/l	< 50	<100	<10	<200	<200	<100	<500	
Aluminium-Al µg/l	596	<50	<50	<200	<100	1590	<500	<8.04
Arsenic (filtered) µg/l	5.1	<1	<1	<1	<1	2.3	<1	
Arsenic – As µg/l	6.2	<1	<1	1.2	2.6	14.5	<1	0.309
Iron (filtered) µg/l	36600	82800	35800	70700	106000	74200	80200	
Iron - as Fe µg/l	66600	80700	51800	78600	112000	137000	88200	<7.62
Cobalt (filtered) µg/l	< 10	<5	<10	<20	13.3	<1	< 50	
Cobalt µg/l	–	–	4.96	<20	<50	<20	< 50	
Copper (filtered) µg/l	27.5	<10	12.4	36	<20	13.3	< 50	
Copper - Cu µg/l	936	8.04	<5	37.6	34.4	215	< 50	0.025
Nitrogen - N mg/l	10.7	52.5	33.4	98.8	77.8	47.9	121	
Vanadium - Filtered µg/l	< 20	<10	<20	<40	<20	<2	< 100	
Vanadium - V µg/l	< 4	<10	<2	<40	<100	<40	< 100	

Appendix 3: Analysis for low level naturally occurring radioactivity

We sent samples to an external laboratory for an analysis of any radioactivity. The analysis showed the presence of naturally occurring radioactive materials (commonly called "NORM") at levels similar to that in many rocks throughout the UK, granite being a common example.

Naturally occurring radioactive materials have been present in rocks since their formation, perhaps billions of years ago. All radioactive materials undergo decay to become more stable, eventually ceasing to be radioactive. Some radioactive materials decay over very long time periods and others more quickly, and so naturally occurring radioactive materials will contain many different radioactive isotopes in differing amounts. The radioactive materials with very long decay times are usually present in larger amounts. Commonly this is radium-226.

The initial analysis of the flowback fluid has shown radium-226 as the radioactive material present at the highest levels, between 14 and 90 Becquerel per litre. Other naturally occurring isotopes present included potassium-40 and radium-228. In comparison the average values for natural radioactivity in soil in western Europe are, potassium-40 - 547 Bq/kg and radium-226 - 40 Bq/kg.

The results of this preliminary analysis have to be viewed with caution, they are only indicative of the radioactivity present. As part of Cuadrilla's application for a permit a radiological impact assessment will be required. In determining the application we will review the radiological impact assessment with regard to public dose constraints as set out in legislation.

Results of Analysis

Gross Alpha and Beta Activity

LGC Ref	Sample	Count date	Gross Alpha Activity as 241plutonium (Bq/kg)	Gross Beta Activity as 40potassium (Bq/kg)
L3004800	Water Sample 14/04/11 A	03-05-11	10.4 ± 3.5	2.7 ± 0.47
	Solids from sample L3004800	03-05-11	1.1 ± 0.3	0.33 ± 0.05
L3005183	Water Sample 03/05/11 A	16-05-11	12.1 ± 4.0	6.2 ± 1.0
	Solids from sample L3005183	16-05-11	2.2 ± 0.6	1.5 ± 0.1
L3005770	Bottle A received 23/05/11	31-05-11	15.8 ± 5.3	12.1 ± 2.0
	Solids from sample L3005770	31-05-11	10.1 ± 2.8	3.4 ± 0.5
L3009542	Water Sample 19/08/11 A	31-08-11	200 ± 59	47 ± 7.8
	Solids from sample L3009542	31-08-11	0.77 ± 0.22	0.27 ± 0.04

Gamma Spectrometry (Bq / kg or Bq / kg equivalent for solids)

LGC Ref.	**L3004801**		**L3005184**		**L3005769**		**L3009542**	
Sample Ref	Water Sample B 14/04/11	Solids from Sample	Water Sample B 03/05/ 11	Solids from Sample	Bottle A Rec'd 23/05/11	Solids from Sample	Water Sample Rec'd 19/08/11	Solids from Sample
Analysis Date	21/04/11	21/04/11	09/05/11	18/05/11	24/05/11	31/05/11	30/08/11	30/08/11
40Potassium	< 1.0	< 1.0	3.5 ± 1.1	< 1.0	3.3 ± 1.9	< 1.0	< 3.0	< 1.0
60Cobalt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.2	< 0.1
137Caesium	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.2	< 0.1
228Actinium	1.7 ± 0.4	< 0.1	2.6 ± 0.5	0.4 ± 0.1	2.9 ± 0.6	1.4 ± 0.3	12 ± 2.5	< 0.2
228Thorium	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 10	<2.0
224Radium	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 1.0
212Lead	0.4 ± 0.1	< 0.5	0.9 ± 0.1	< 0.5	0.7 ± 0.1	< 0.5	< 0.5	< 0.5
212Bismuth	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 2.0	< 0.5
208Thallium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
234Thorium	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 6.0	< 1.0
226Radium	14 ± 2.1	< 0.2	16 ± 2.1	2.5 ± 0.4	17 ± 2.3	7.2 ± 1.5	90 ± 12	< 1.0
214Lead	1.4 ± 0.2	< 0.5	6.0 ± 0.7	1.6 ± 0.2	2.3 ± 0.3	2.6 ± 3.3	50 ± 5.6	< 0.5
214Bismuth	0.9 ± 0.2	< 0.5	5.1 ± 0.6	1.3 ± 0.2	2.1 ± 0.3	2.3 ± 0.3	41 ± 4.6	< 0.5
235Uranium	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.3	< 0.1
227Thorium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 2.0	< 0.5
223Radium	< 0.5	< 0.5	2.1 ± 0.6	< 0.5	< 0.5	< 0.5	< 2.5	< 0.5
241Americium	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.5	< 0.1

Glossary

- Fracking fluid - fluid injected in to the exploration well
- Flowback fluid - water with dissolved and suspended minerals that comes back out of a exploratory well (this can also be called return fluid, or return fracking fluid)

Flowback – 03rd Nov 2011

3rd Nov 2011; Environment Agency Analysis of Flowback

Environment Agency

Shale Gas

North West - Monitoring of Flow back water

3rd November 2011

Results

The Bowland Shale rock formation in Lancashire is a potential source of unconventional shale gas and is described by the British Geological Society as offering the best potential in the UK.

Cuadrilla Resources are licensed by the Department of Energy and Climate Change to explore in this area. They have permission to drill up to five exploratory wells. They have drilled two and are currently drilling a third. One of these has progressed to hydraulic fracturing - Preese Hall.

Environmental regulation

Our role is to help ensure that the environment is protected from the potential impacts of exploration and this includes ensuring that the disposal of the "flow back" water from the exploratory wells is managed properly.

What is flow back water?

Some of the water that is injected in to the shale rock during hydraulic fracturing returns to the surface through the drilled well. This is often called the "flow back" water. Typically around a quarter of the water injected will return to the surface over a period of weeks to a few months. This flow back water is very saline, and contains minerals dissolved from the rocks as well as small particles of the rock.

Because the water has a high mineral content it has to be disposed of carefully, with the appropriate permits granted, where necessary, for the chosen disposal route.

What analysis did we do and what did we find?

We took samples of the flowback fluid and sent them to our own laboratories for analysis.

All of the chemicals found are those which we would expect to find in shale rock and are naturally occurring.

There are notably high levels of sodium, chloride, bromide and iron, as well as higher values of lead, magnesium and zinc compared with the local mains water that is used for injecting into the shale.

Analysis for us by other laboratories showed that they also contained very low levels of naturally radioactive minerals - similar to the levels found in granite rock.

Where does the flow back water go?

The flow back water produced to date from the Preese Hall exploration site has been stored in double skinned tanks on site. It was then transported to a waste water treatment works at Davyhulme .

www.environment-agency.gov.uk

The waste water treatment works already treats many other industrial effluents from the Manchester area and holds a permit from the Environment Agency to discharge to the Manchester Ship Canal. It is capable of dealing with the levels of minerals contained in the flow back water.

Do they need a permit?

On 1 October 2011, new limits were specified in Schedule 23 of the Environmental Permitting Regulations 2010. This supersedes previous limits. Cuadrilla want to continue disposing of these fluids to the waste water treatment works. A permit is now required as the levels measured combined with the expected quantities of flow back water exceed new limits. We have told them that they need to apply to us for a permit and provide us with more information so we can assess their proposal.

What is happening to the flow back fluid now?

Currently the flow back water is being stored in double skinned tanks on site pending a permit application.

Appendix 1 A comparison of the mineralisation of this water with other waters

Different water sources have different levels of these chemicals. Below is a table to give an indication of how the maximum levels in the flow back waters compare to those in other water sources.

	Sea Water (grams per litre)	The Dead Sea (grams per litre)	Flow Back Water (grams per litre)
Sodium	10.1	36.3	28.4
Chloride	19.4	230.4 (for chloride plus bromide)	75.0
Bromide			0.9
Magnesium	1.3	45.9	0.6
Potassium	0.4	7.8	0.05

Appendix 2: Table of Environment Agency dissolved salts sample analysis

Notes to support table

- Mains water with small amounts of additives are injected into the exploratory well - this is the fracking fluid.

customer service line
03708 506 506
incident hotline
0800 80 70 60
floodline
0845 988 1188
www.environment-agency.gov.uk

- As a comparison we are using the figures for the water from United Utilities in the detailed table (below). It is a typical analysis for mains tap water in the Singleton area. (sourced from United Utilities web pages).

- The variation between this and the flow back analysis indicates the minerals which have been taken from the shale formation during the fracking process.

- The analysis of the flowback water is reported in either micrograms per litre (μg/l), or milligrams per litre (mg/l). (Note 1 mg/l = 1000 μg/l). Filtered means filtered to remove solids.

SITE	**Cuadrilla Drill Rig**	**Cuadrilla Drill Rig**	**Cuadrilla Drill Rig**	**Cuadrilla Drill Rig**	**Cuadrilla Drill Rig**	**Mains water (from United Utilities web data) average concentration**
DATE	07/04/11	14/04/11	28/04/11	18/05/11	14/06/11	
TIME	13:20	13:30	11:10	14:00	09:55	
Conductivity at 25oC μs/cm	–	–	–	150614	133730	299
pH	–	–	–	6.35	7.06	7.54
Lead (filtered) μg/l	179	<20	<2	<40	<40	
Lead - as Pb μg/l	600	<10	<10	<40	44.9	<0.417
Mercury (filtered) μg/l	0.01	<0.01	0.013	<0.01	<0.01	
Mercury - Hg μg/l	0.024	<0.01	<0.01	<0.01	0.012	<0.0127
Cadmium (filtered) μg/l	0.674	<1	1.47	<2	<2	
Cadmium - Cd μg/l	1.29	<0.5	<0.5	<2	<1	<0.04
Bromide mg/l	–	–	242	854	608	<0.444
Chloride Ion mg/l	15400	34400	22200	75000	64300	13.5

Sodium (filtered) mg/l	7950	15100	9330	28400	>200	
Sodium - Na mg/l	no bottle	15100	9380	28400	23600	22.9
Potassium (filtered) mg/l	23.2	46.4	37.8	82.1	>20	
Potassium - K mg/l	28.8	52.3	40.6	–	–	
Magnesium (filtered) mg/l	177	>50	397	–	–	
Magnesium - Mg mg/l	no bottle	586	401	1470	1350	9.21
Phosphorus - P mg/l	1.28	0.0771	<0.02	<0.1	<0.5	
Chromium (filtered) µg/l	< 3	<5	0.565	28	<10	
Chromium - Cr µg/l	25	4.03	<3	20.5	53.9	<0.349
Zinc – (filtered) µg/l	297	<50	53.6	142	411	
Zinc - as Zn µg/l	565	51.5	<30	173	435	
Nickel – (filtered) µg/l	13.8	<10	21.5	<20	<20	
Nickel - Ni µg/l	20.3	<5	<5	<20	<20	1.20
Silver (filtered) µg/l	< 10	<5	<10	<20	<10	
Silver µg/l	–	–	<1	<20	<10	
Aluminium (filtered) µg/l	< 50	<100	<10	<200	<200	
Aluminium-Al µg/l	596	<50	<50	<200	<100	<8.04
Arsenic (filtered) µg/l	5.1	<1	<1	<1	<1	
Arsenic – As µg/l	6.2	<1	<1	1.2	2.6	0.309
Iron (filtered) µg/l	36600	82800	35800	70700	106000	
Iron - as Fe µg/l	66600	80700	51800	78600	112000	<7.62

Cobalt (filtered) µg/l	< 10	<5	<10	<20	13.3	
Cobalt µg/l	–	–	4.96	<20	<50	
Copper (filtered) µg/l	27.5	<10	12.4	36	<20	
Copper - Cu µg/l	936	8.04	<5	37.6	34.4	0.025
Nitrogen - N mg/l	10.7	52.5	33.4	98.8	77.8	
Vanadium - Filtered µg/l	< 20	<10	<20	<40	<20	
Vanadium - V µg/l	< 4	<10	<2	<40	<100	

Appendix 3: Environment Agency low level naturally occurring radioactivity sample analysis

We also sent samples to an external laboratory for an analysis of any radioactivity. The analysis showed the presence of naturally occurring radioactive materials (commonly called NORM) at levels similar to that in many rocks throughout the UK, granite being a common example.

Naturally occurring radioactive materials have been present in rocks since their formation, perhaps billions of years ago. All radioactive materials undergo decay to become more stable, eventually ceasing to be radioactive. Some radioactive materials decay over very long time periods and others more quickly, and so naturally occurring radioactive materials will contain many different radioactive isotopes in differing amounts. The radioactive materials with very long decay times are usually present in larger amounts. Commonly this is Radium 226.

The initial analysis of the flowback fluid has shown Radium 226 as the radioactive material present at the highest levels, between 14 and 90 Becquerel per litre. Other naturally occurring isotopes present included potassium-40 and Radium-228.

On 1 October 2011, revised levels for naturally occurring radioactive materials were introduced into Schedule 23 of the Environmental Permitting Regulations 2010. Based on initial analysis of the radioactivity in the flowback fluid Cuadrilla will require an Environmental Permit to store and dispose of the flowback fluid.

The results of this preliminary analysis have to be viewed with caution, they are only indicative of the radioactivity present. As part of Cuadrilla's application for a permit a radiological impact assessment will be required. In determining the application we will review the radiological impact assessment with regard to public dose constraints as set out in legislation.

Results of Analysis

Gross Alpha and Beta Activity

LGC Reference	Sample	Count Date	Gross Alpha Activity as ^{241}Pu (Bq/kg)	Gross Beta Activity as ^{40}K (Bq/kg)
L3004800	Water Sample "14/04/11" A	03-05-11	10.4 ± 3.5	2.7 ± 0.47
	Solids from Sample L3004800	03-05-11	1.1 ± 0.3	0.33 ± 0.05
L3005183	Water Sample "03/05/11" A	16-05-11	12.1 ± 4.0	6.2 ± 1.0
	Solids from Sample L3005183	16-05-11	2.2 ± 0.6	1.5 ± 0.1
L3005770	Bottle A Received 23/05/11	31-05-11	15.8 ± 5.3	12.1 ± 2.0
	Solids from Sample L3005770	31-05-11	10.1 ± 2.8	3.4 ± 0.5

Gamma Spectrometry (Bq / kg or Bq / kg equivalent for solids)

LGC Ref.	L3004801		L3005184		L3005769	
Sample Ref	Water Sample B 14/04/11	Solids from Sample L3004801	Water Sample B 03/05/11	Solids from Sample L3005184	Bottle A Rec'd 23/05/11	Solids from Sample L3005769
Analysis Date	21-04-11	21-04-11	09-05-11	18-05-11	24-05-11	31-05-11
^{40}Potassium	< 1.0	< 1.0	3.5 ± 1.1	< 1.0	3.3 ± 1.9	< 1.0
^{60}Cobalt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
^{137}Caesium	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
^{228}Actinium	1.7 ± 0.4	< 0.1	2.6 ± 0.5	0.4 ± 0.1	2.9 ± 0.6	1.4 ± 0.3
^{228}Thorium	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0
^{224}Radium	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0
^{212}Lead	0.4 ± 0.1	< 0.5	0.9 ± 0.1	< 0.5	0.7 ± 0.1	< 0.5
^{212}Bismuth	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
^{208}Thallium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
^{234}Thorium	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
^{226}Radium	14 ± 2.1	< 0.2	16 ± 2.1	2.5 ± 0.4	17 ± 2.3	7.2 ± 1.5
^{214}Lead	1.4 ± 0.2	< 0.5	6.0 ± 0.7	1.6 ± 0.2	2.3 ± 0.3	2.6 ± 3.3
^{214}Bismuth	0.9 ± 0.2	< 0.5	5.1 ± 0.6	1.3 ± 0.2	2.1 ± 0.3	2.3 ± 0.3
^{235}Uranium	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
^{227}Thorium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
^{223}Radium	< 0.5	< 0.5	2.1 ± 0.6	< 0.5	< 0.5	< 0.5
^{241}Americium	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

Glossary

- Fracking fluid - fluid injected in to the exploration well
- Flow back water - water that comes back out of a exploratory well (this can also be called return fluid, or return fracking fluid)