Proposed Shale Gas Exploration Wells
Bowland Basin, Lancashire
Cuadrilla Resources

Case Study: Environmental Assessments

Des Correia, Director, Arup
November 2014

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- Arup / Cuadrilla Resources
- Proposed Projects
- Environmental Risk Assessment (ERA)
- Environmental Impact Assessment (EIA)
- Stakeholder Consultation
- Planning Applications, Consultation & Determination
- Permit Applications, Consultation, Granting
- Questions

* Belfast, Bristol, Cardiff, Edinburgh, Glasgow, Leeds, Liverpool, Manchester, Midlands Campus, Newcastle, Nottingham, Sheffield, Winchester

Globally advising, planning, designing, managing the delivery and operation of assets in Cities, Transport, Energy and Water. Since 1946, our enduring values and unique independent ownership have fostered a culture of collaborative working.

Cuadrilla

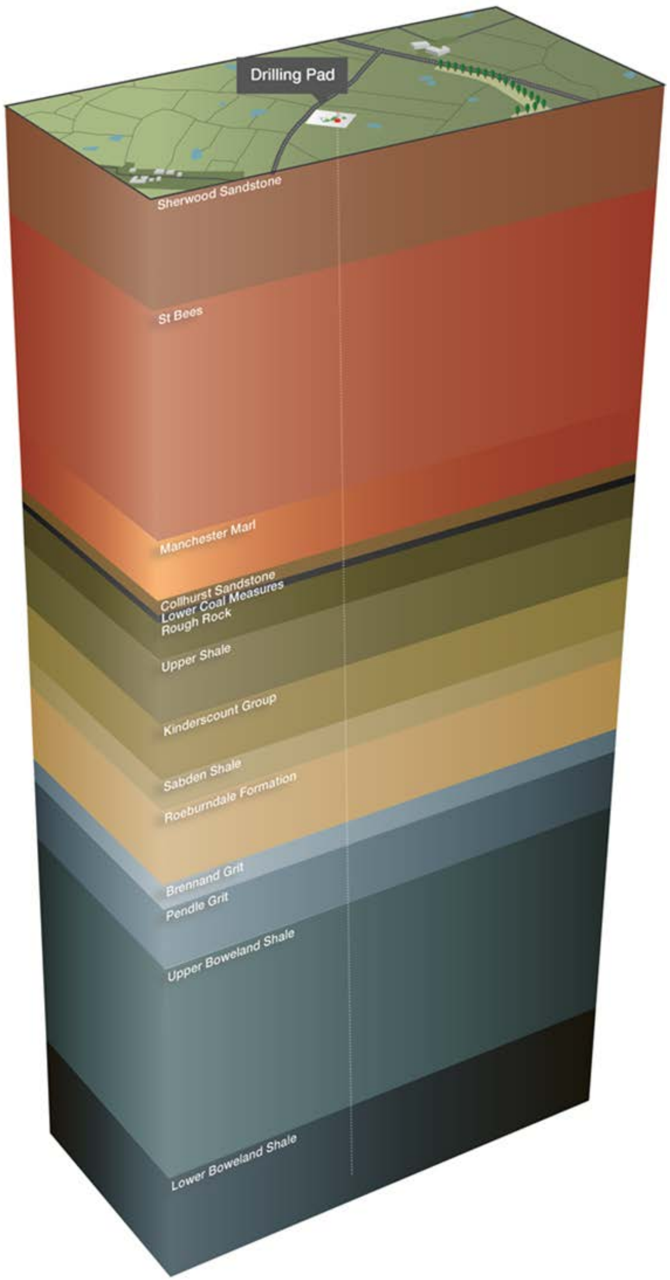
Cuadrilla – PEDL 165, Bowland Basin

Centrica Energy

We are an international business operating in the UK, Europe, North America and Trinidad and Tobago, delivering a balanced mix of gas and oil production, power generation and energy trading.

Centrica – Cuadrilla JV Partner for Bowland Basin PEDL 165

- Cuadrilla - UK company, formed 2007. Exploration and production company; pioneer in UK shale gas.
- Over 3,000 gas & oil wells world-wide. “Model company” for UK unconventional exploration. Acutely aware of responsibilities - safety, environmental protection and local communities.
- 70 staff in UK. Main UK contracting partner - PR Marriott Drilling Ltd - over 60 years of UK drilling experience.
- Privately owned: Management, AJ Lucas and Riverstone LLC.



Shale Gas Exploration

Now more than ever Britain needs more home-grown energy. Shale gas and oil represents a huge economic opportunity for local communities. UK investment could reach £33 billion between 2016 and 2032 or £3.7 billion a year and support around 60,000 jobs in the oil, gas, construction, engineering and chemicals sectors.

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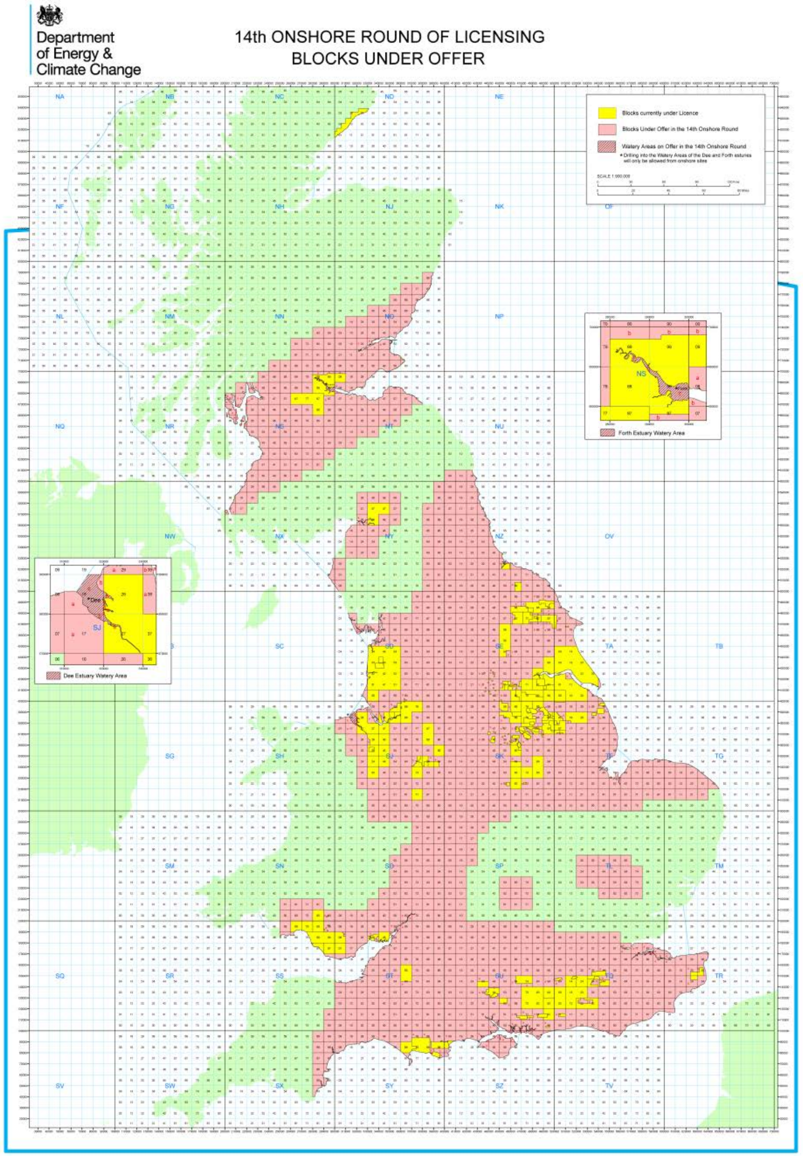
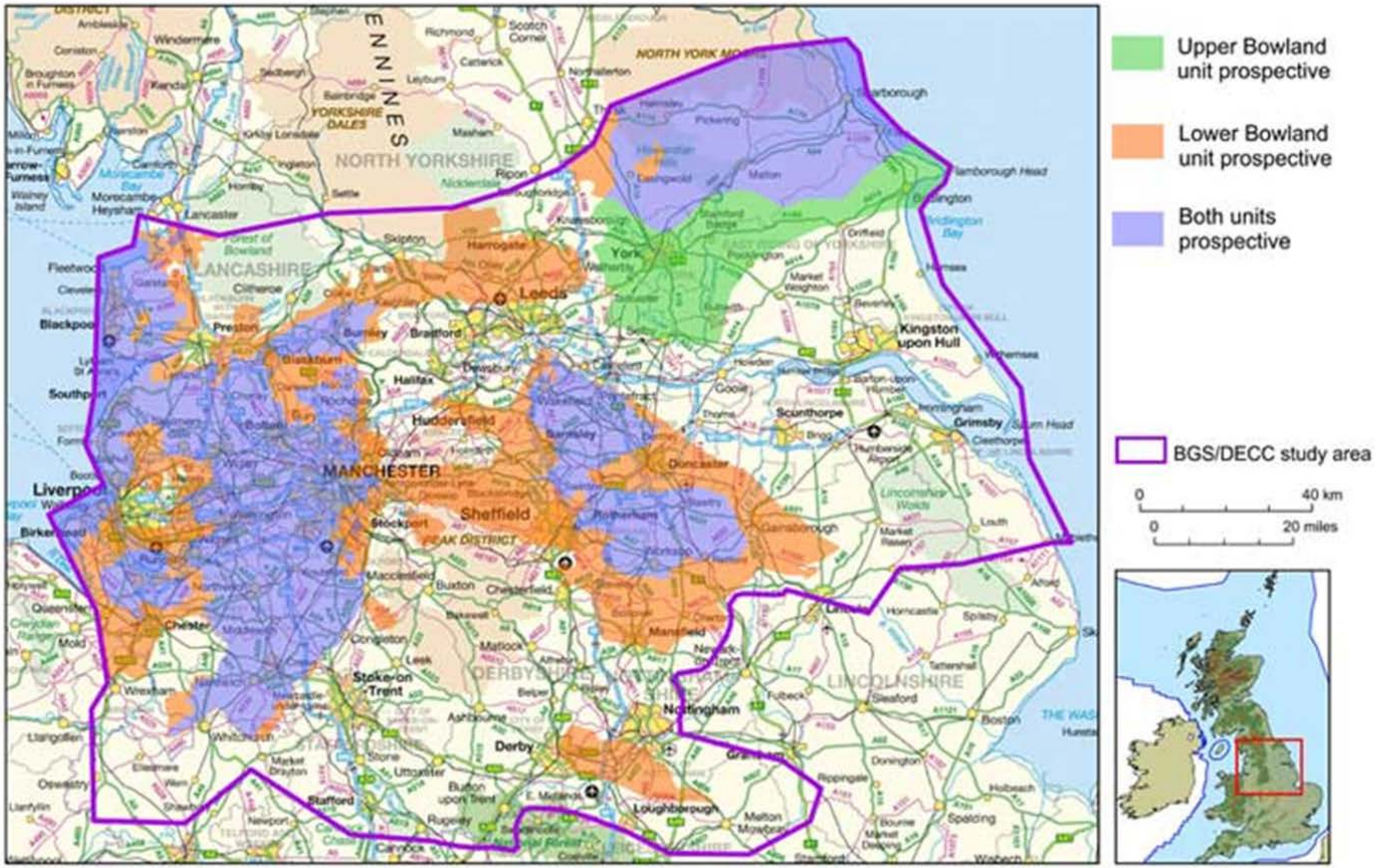
- 28 July 2014: Ministers opened bidding process for companies seeking licenses to explore for onshore oil and gas, to help discover how the gas under our feet can help power our homes.
- Applications for Licenses closed 28th October 2014.
- License Awards Early 2015?



BGS estimates 1,300 trillion cubic feet of shale gas in Bowland shale basin alone. Their upper estimate is almost twice that, 2,281 tcf. This would make it by far the biggest shale basin in the world. *(10% of Bowland Shale = 130 tcf – or about 50 years of total UK consumption)*



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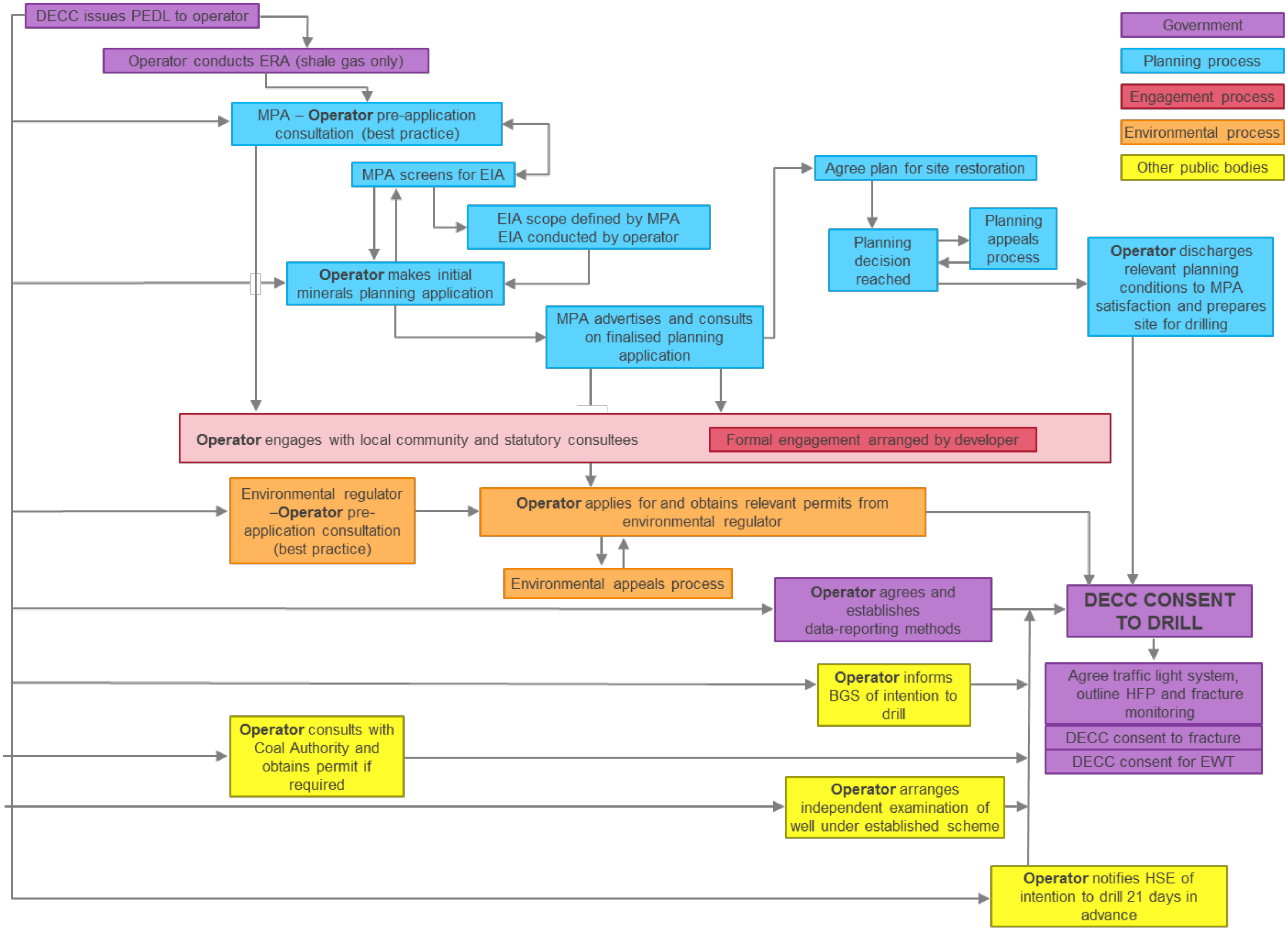
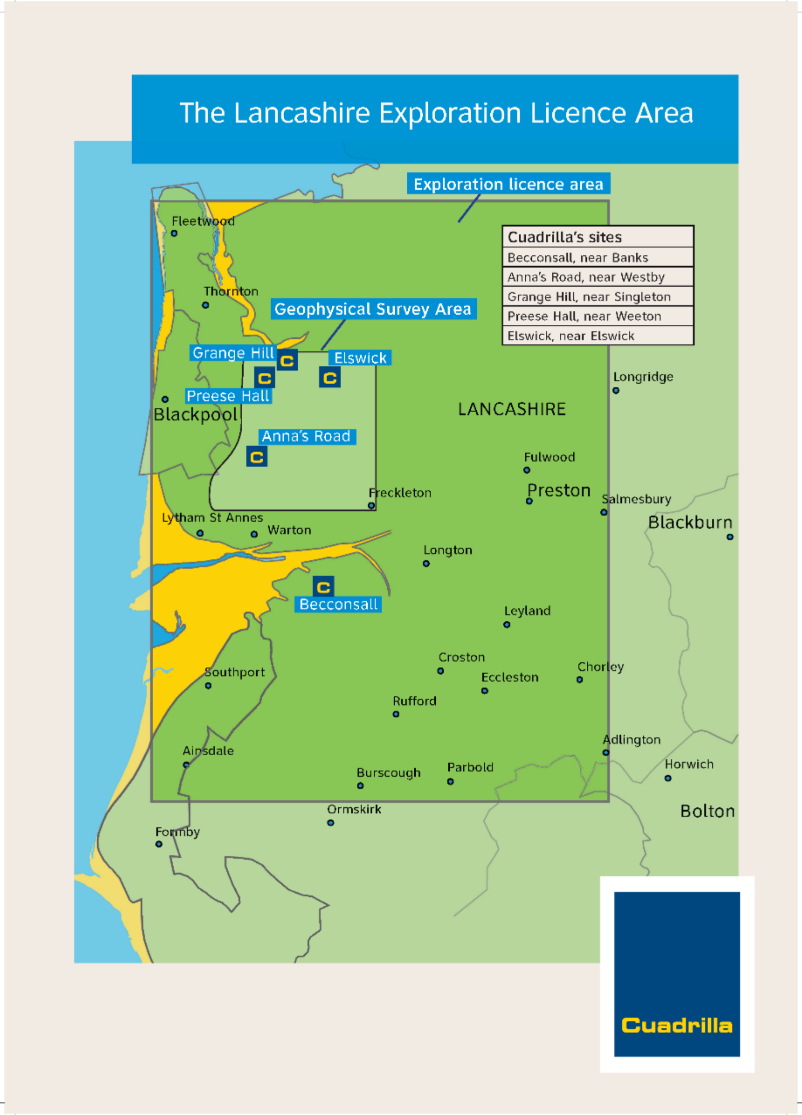
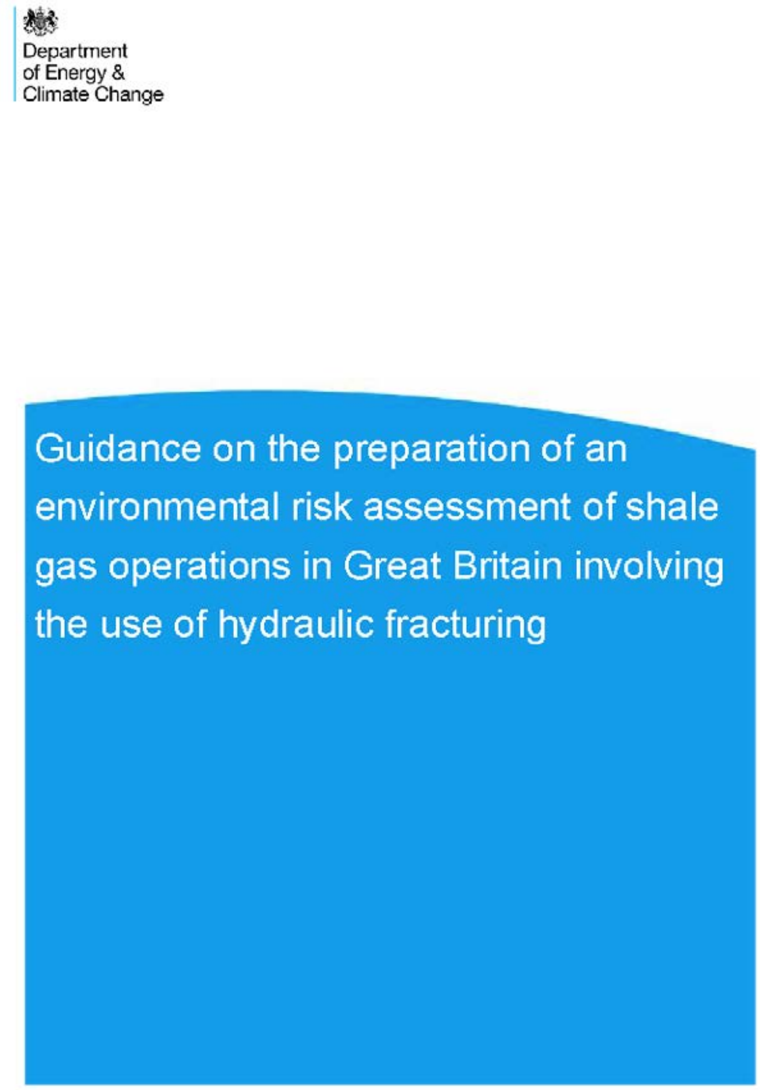

DECC issues PEDL to operator
Operator conducts ERA (shale gas only)
MPA – Operator pre-application consultation (best practice)
MPA screens for EIA
EIA scope defined by MPA
EIA conducted by operator
Operator makes initial minerals planning application
MPA advertises and consults on finalised planning application
Agree plan for site restoration
Planning decision reached
Planning appeals process
Operator discharges relevant planning conditions to MPA satisfaction and prepares site for drilling
Government
Planning process
Engagement process
Environmental process
Other public bodies
Operator engages with local community and statutory consultees
Formal engagement arranged by developer
Environmental regulator –Operator pre-application consultation (best practice)
Operator applies for and obtains relevant permits from environmental regulator
Environmental appeals process
Operator agrees and establishes data-reporting methods
DECC CONSENT TO DRILL
Operator informs BGS of intention to drill
Agree traffic light system, outline HFP and fracture monitoring
DECC consent to fracture
DECC consent for EWT
Operator consults with Coal Authority and obtains permit if required
Operator arranges independent examination of well under established scheme
Operator notifies HSE of intention to drill 21 days in advance

- Planning application strategy including stakeholder and public consultation and post planning submission.
- Site Selection.
- Environmental Risk Assessments.
- Planning applications, Environmental Impact Assessments and other and studies required in support
- Negotiations required to obtain planning permissions
- Support through any legal challenges which may arise.



Cuadrilla: PEDL 165

- Overview of environmental & human health risks.
- ERA - all shale gas projects with hydraulic fracturing. Early, before planning application. Involve stakeholders & local communities.
- Entire life cycle, including waste disposal, well abandonment, and induced seismicity.
- Inform other assessments (EIA), where required.
- Risk vs Impact vs Concern

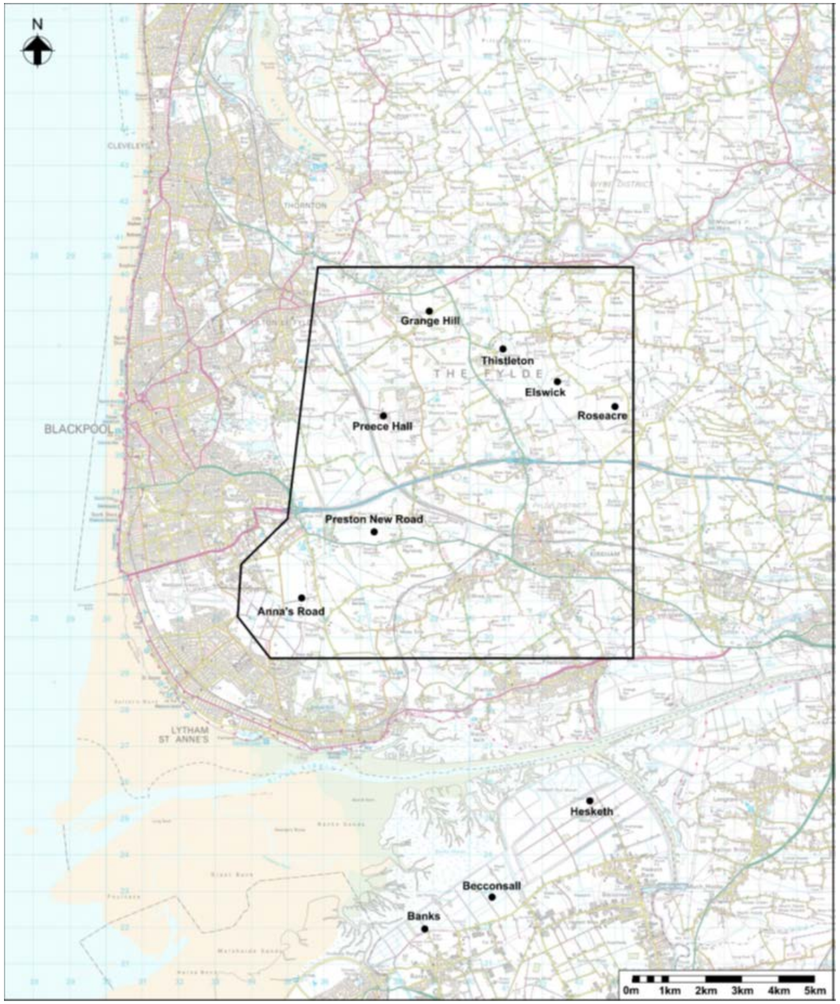

Department of Energy & Climate Change

Guidance on the preparation of an environmental risk assessment of shale gas operations in Great Britain involving the use of hydraulic fracturing

Risk	L	C	Risk
1: Gas escapes at, or above ground surface	Low	Low	Low
2: Uncontrolled release of gas and fluid from the well bore at surface during drilling operations (“Blowout”)	V Low	Mod	Low
3: Contamination of groundwater from sub-surface sources	Low	Low	Low
4: Spillage of contaminants on site surface causes pollution	Low	Low	Low
5: Inadequate management of site waste treatment	V Low	Mod	Low
6: Spills in transit which pollute local environment	Low	Low	Low
7: Induced seismic event causes damage to local infrastructure	Low	Low	Low
8: Subsidence of ground related to gas extraction	NPP	NPP	NPP
9: Road traffic accidents involving site vehicles cause damage	Low	Low	Low
10: Water shortages or low pressure during hydraulic fracturing	V Low	Low	Low
11: Increased risk of flooding due to site operations	V Low	Mod	Low
12: Damaging archaeological artefacts or listed buildings	Low	Low	Low
13: Dust particles from proppants inhaled or released into air	V Low	Low	Low
14: Lack of long-term well integrity leads to contamination	Low	Low	Low
15: Radioactive emissions from borehole testing materials	V Low	Low	Low

Risk 14 Lack of long-term well integrity leads to contamination of groundwater due to migration of gas or contaminants post-abandonment	
Source	Ground gases, residual drilling fluid and hydraulic fracturing fluid remaining in the well and the target formation, naturally occurring poor quality groundwater
Pathway	• Migration of gas or contaminants via the plugged and abandoned well due to loss of well integrity. • Migration of contaminants via induced fractures to shallow groundwater
Receptor	Shallow groundwater and users of groundwater. Air quality
Project Phase	Well suspension and post well abandonment
Mitigation Measures embedded in the Project	The Preston New Road wells will be drilled, constructed and integrity tested in accordance with regulatory guidance (DECC, HSE and EA) and industry guidance (Oil and Gas UK and UKOOG), providing multiple barriers between the shallow groundwater and deep underlying hydrocarbon production zones. Wells will be plugged and abandoned in accordance with Oil & Gas UK guidelines, BSOR regulations and Environmental Permitting Regulations Groundwater, methane emissions and ground gas monitoring will be undertaken post abandonment and regulated by the EA through the environmental permit prior to its surrender. Cuadrilla will fully disclose the composition of the proposed fracturing fluid prior to use and will only use substances assessed and approved by the EA. As part of the site decommissioning process, aftercare operations and monitoring will be agreed with relevant regulatory stakeholders. The aftercare operations and monitoring will be performed in accordance with regulatory requirements at the time when site decommissioning is performed.
Likelihood	Low
Consequence	Low
Risk Score	Low
Justification for Risk Score	The well abandonment process is well established for both onshore and offshore, requiring notification to HSE and in accordance with HSE, industry and DECC well abandonment best practice. There is no post-abandonment pressure gradient to cause residual fracturing fluid to travel upwards from fractured zone at over >8,000feet depth to near surface. Natural geological barriers (e.g. Manchester Marl) are present.
Comments	Details of restoration of the site will be part of the planning application. The site will be restored to agriculture with aftercare period agreed with the landowner and planning authority. Further technical detail to be provided in the Environmental Statement which will present a detailed contamination risk assessment.

- 3 Stage Process
  - Suitable Geology
    - Thickest shale in UK
    - Available geological data.
    - 3D geophysical survey - avoid HF near regional faults.
    - HF in relatively flat lying, continuous thick sections of shale.
  - Tier 1 Constraints
    - European / national designations.
    - Nationally heritage assets.
    - Groundwater Source Protection Zone 1.
    - Flood Risk – avoid risk zone 3b.
  - Tier 2 Constraints
    - Transport & Utilities connections.
    - Local Environmental Constraints
    - Planning Constraints - Local planning policy.
    - Land Ownership Issues.



Alternative Sites Considered

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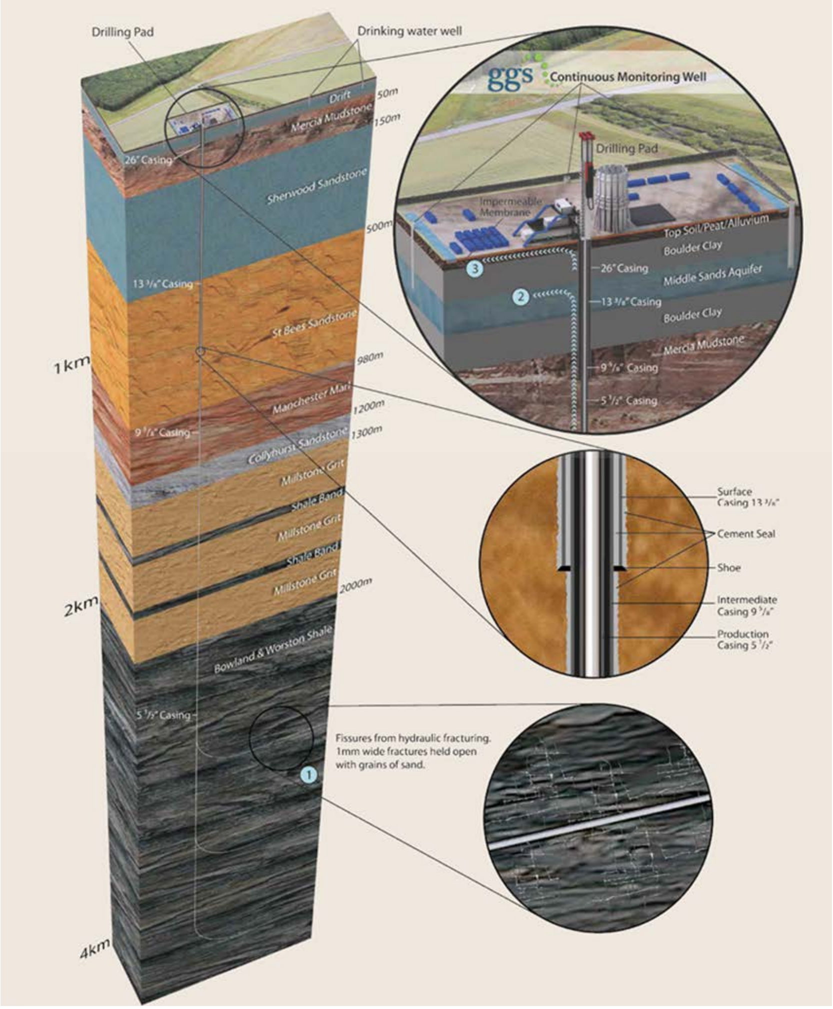

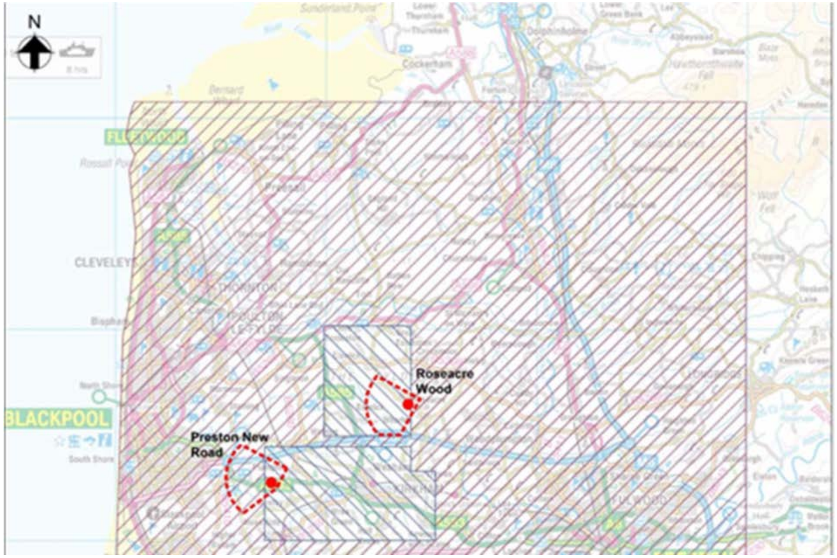

Current Cuadrilla Shale Gas Exploration Applications

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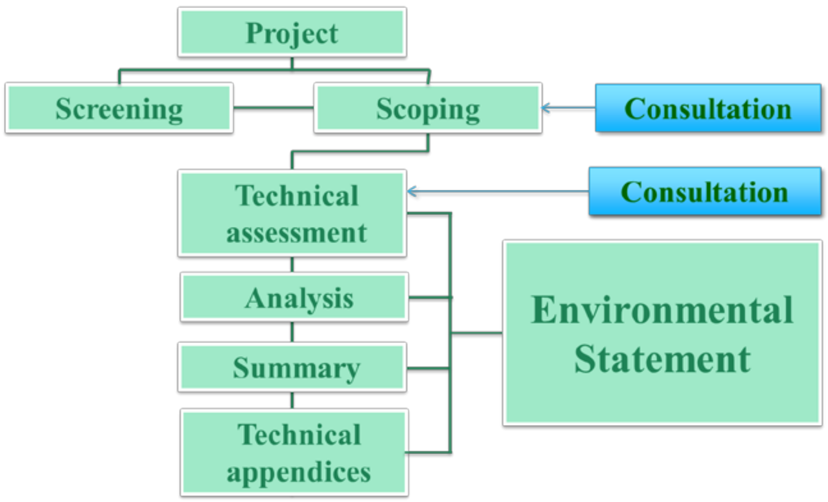
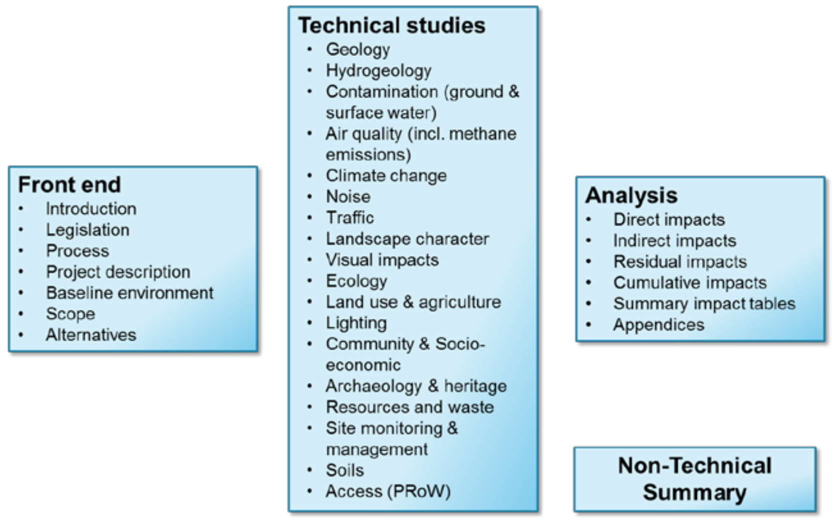
- 1st shale gas sites in UK subject to EIA. Detail greater than typical for temporary hydrocarbon exploration project. Future EIAs likely to be refined.
- EIA: Cuadrilla decision.
- EIA: Town & Country Planning (Environmental Impact Assessment) Regulations 2011 (SI 2011 No. 1824) (referred to as the 'EIA Regulations'), leading to preparation of Environmental Statement (ES).

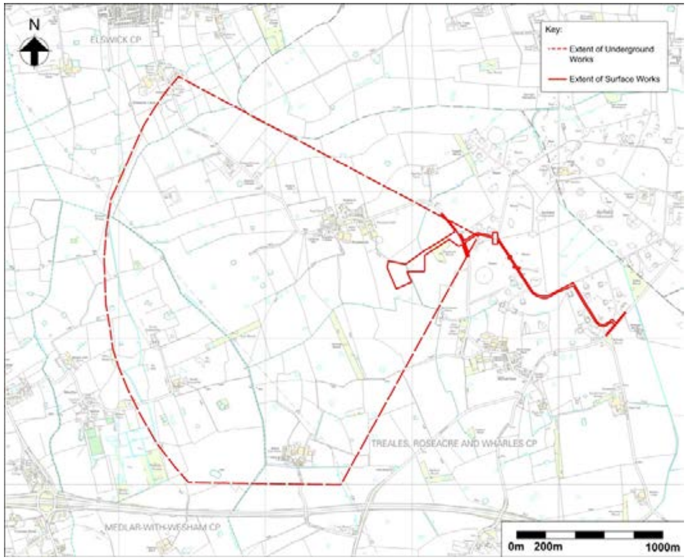


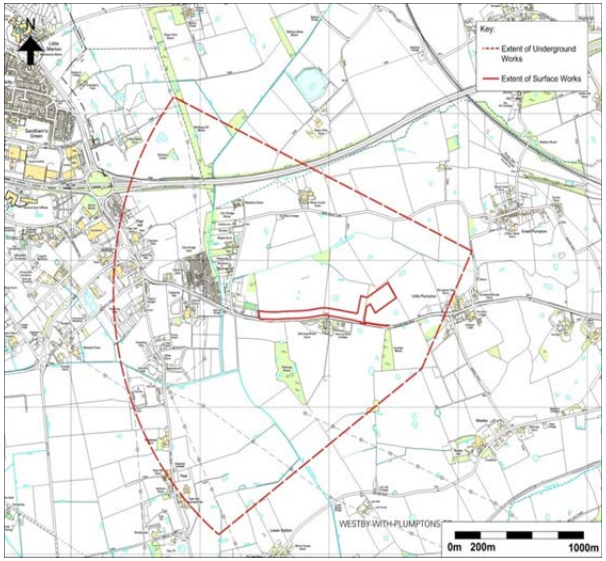
Environmental Impact Assessment (EIA) Process



Environmental Statement

- Application Areas:
  - Extent of surface works.
  - Plans show maximum extent of below ground area for which planning consent is required.
  - Final extent and direction of horizontal wells below ground not currently know until first vertical well is drilled and investigated – shown as a dotted arc on the application plans.





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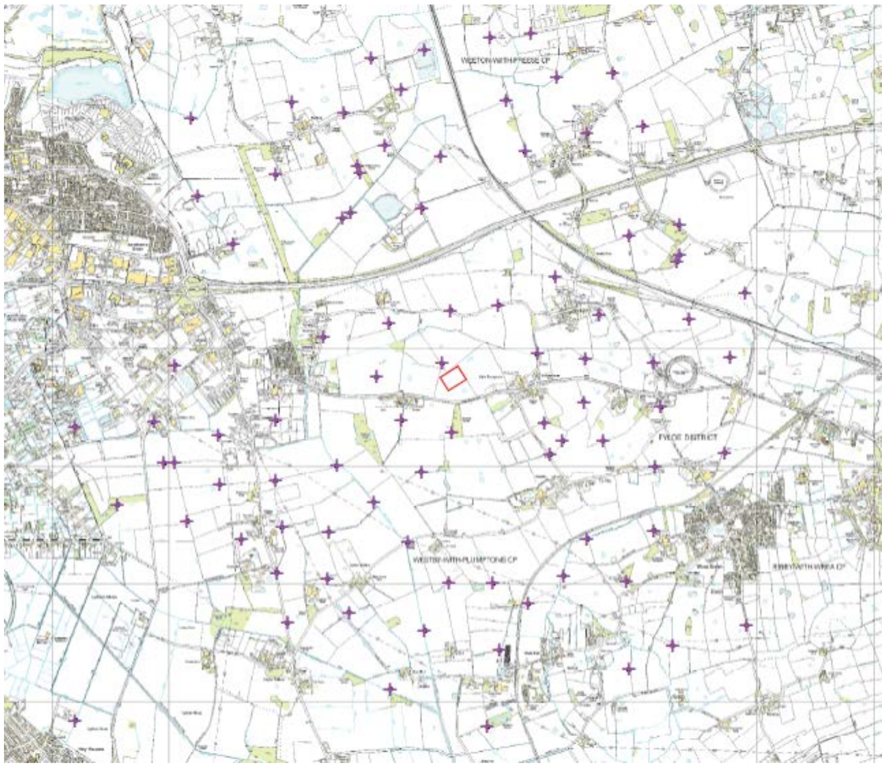


Surface Array (Traffic light system)

8 locations

Small plastic kiosk (1.1 m height)

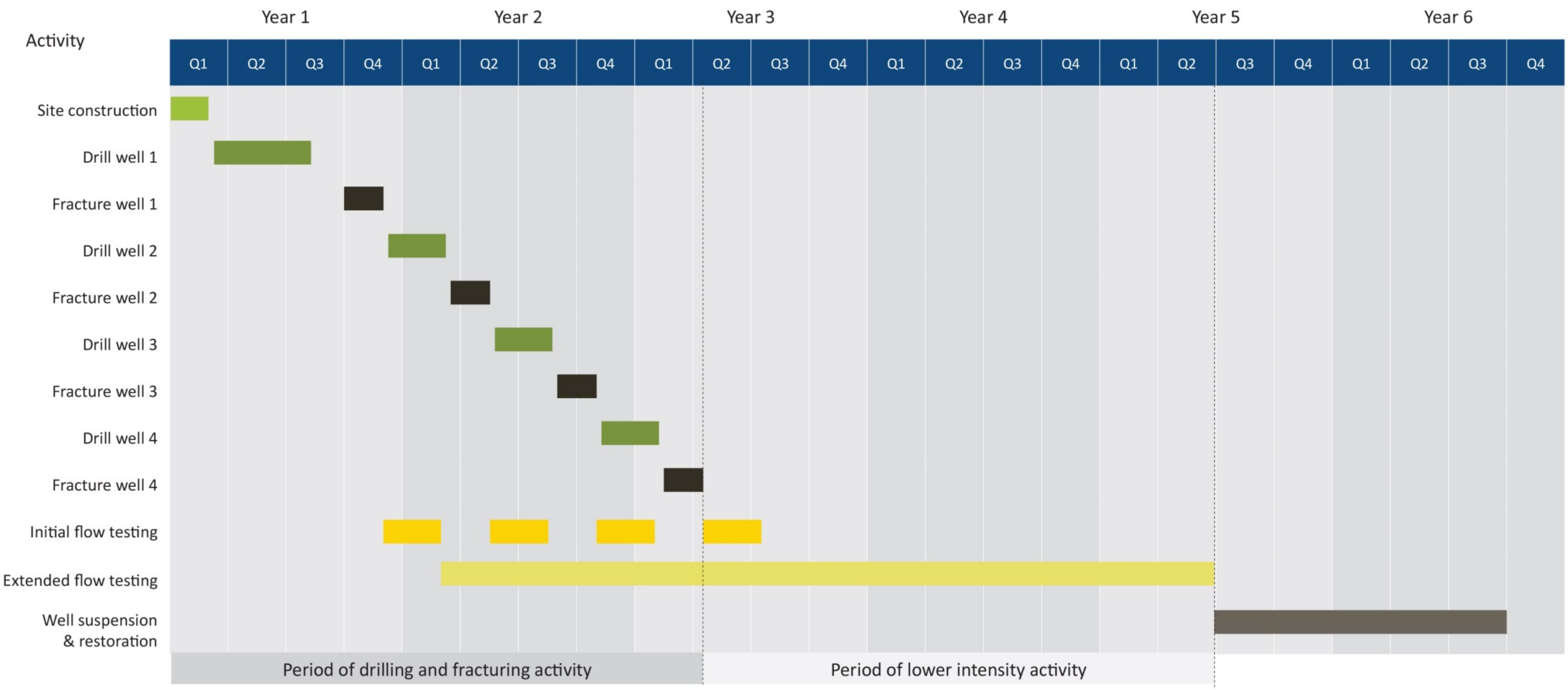
Monitor induced seismicity

Buried Array

80 locations

100m below ground

Measure extent and rate of fracture propagation



Timeline for Exploration

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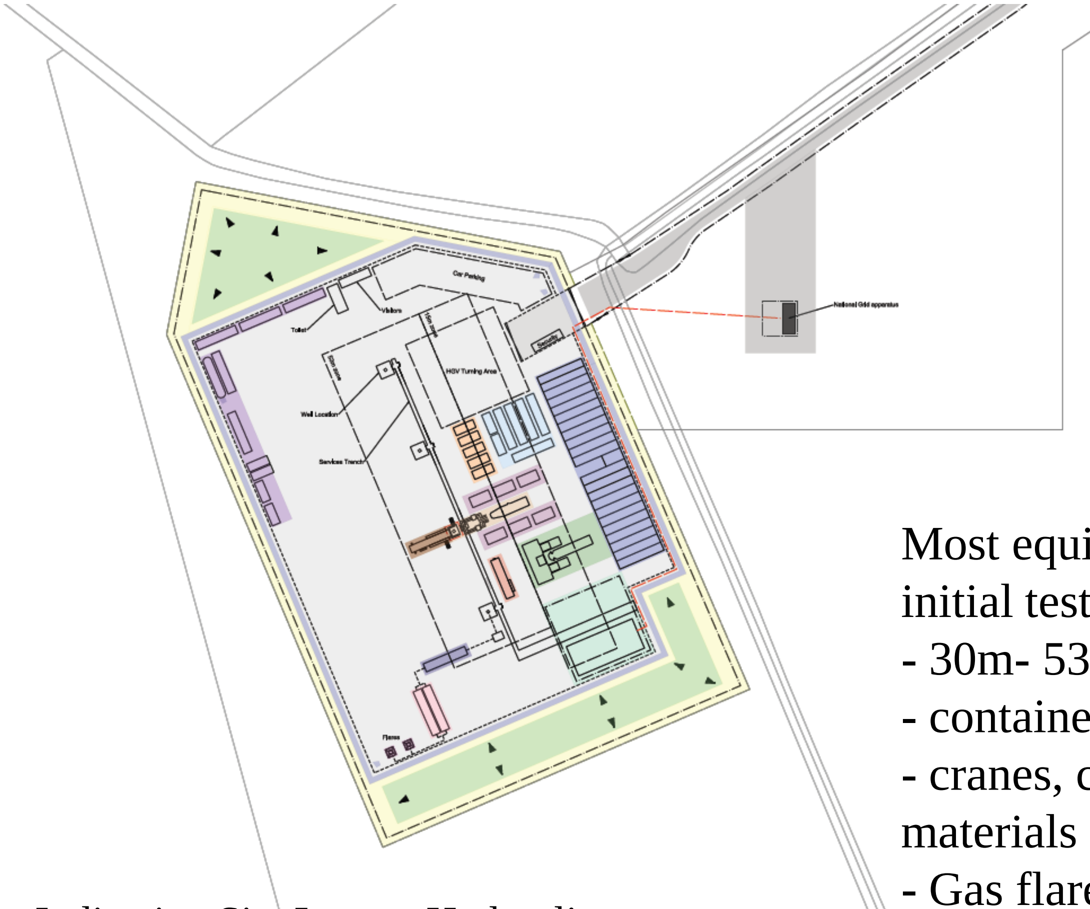
Construction activities and Site Equipment



Indicative Site Layout Hydraulic Fracturing, Initial Flow Testing and Extended Flow Testing

Example of plastic membrane and surface water drainage ditch

Most equipment at drilling, fracturing and initial testing:
- 30m- 53m drilling unit
- containers for storage, offices and welfare
- cranes, cementing equipment, generators and materials
- Gas flare stack (approx 10m height)
- work-over rig (approx 15m height)
- Hydraulic fracturing pumps and tower (approx 25m)

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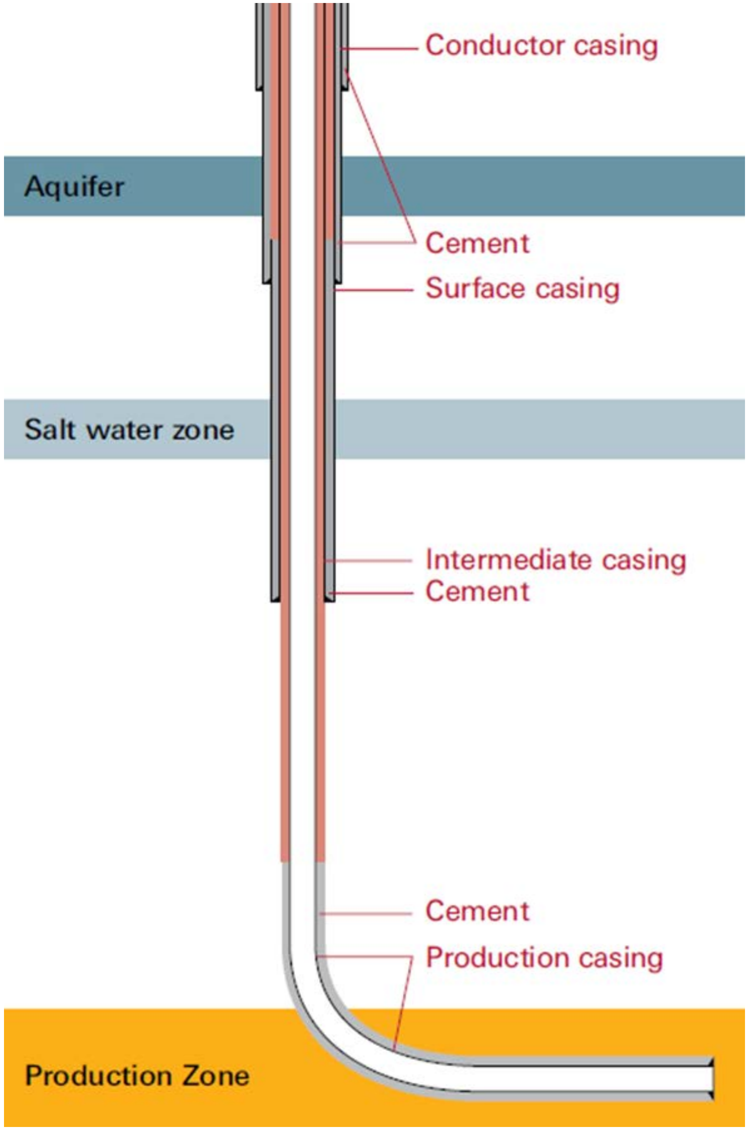

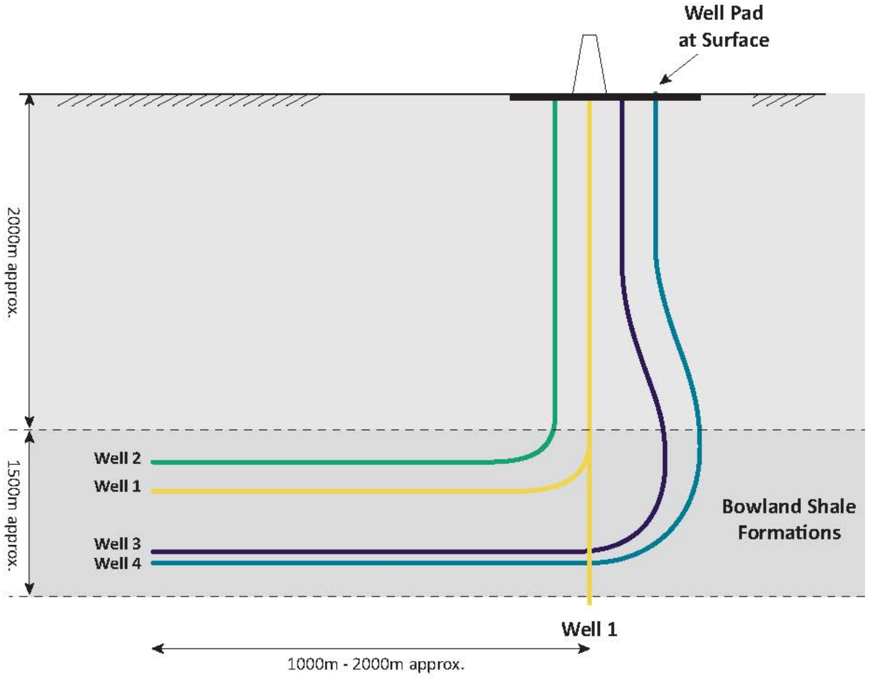

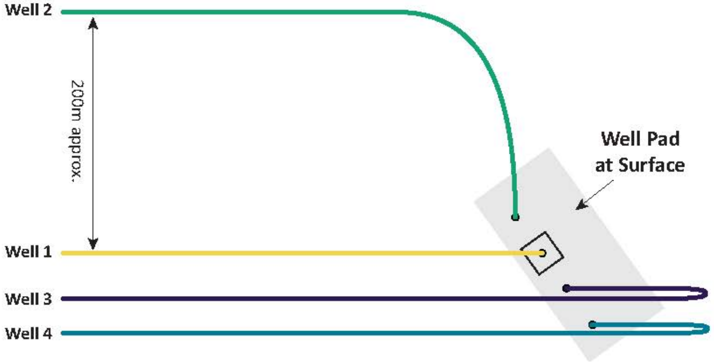

Multiple well configuration

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- Air Quality
- Archaeology & Cultural Heritage
- Greenhouse Gas Emissions
- Community & Socio-Economics
- Ecology
- Hydrogeology & Ground Gas
- Induced Seismicity
- Land Use
- Landscape & Visual Amenity
- Lighting
- Noise
- Resources & Waste
- Transport
- Water Resources
- Public Health
- Cumulative and in-combination effects

Lancashire County Council

ARUP
The Arup Campus
Blythe Gate
Blythe Valley Park
Solihull
B90 8AE

Phone: 01772 534130
Email: DevCon@lancashire.gov.uk
Your ref: 230382-00
Our ref: LCC/2014/0020 /JMH/MK
Date: 11 March 2014

Dear Mr Richardson

THE TOWN AND COUNTRY PLANNING (ENVIRONMENTAL IMPACT ASSESSMENT) REGULATIONS 2011, REGULATION 13 - SCOPING OPINION
APPLICATION: LCC/2014/0020
PROPOSAL: SCOPING OPINION FOR ENVIRONMENTAL STATEMENT TO ACCOMPANY APPLICATION FOR CONSTRUCTION OF A WELL PAD, DRILLING AND HYDRAULIC FRACTURING OF FOUR EXPLORATORY BOREHOLES, TESTING PROCEDURES AND RESTORATION OF SITE.
LOCATION: LAND AT ROSEACRE WOOD, OFF ROSEACRE LANE, ROSEACRE, ELSWICK, NR KIRKHAM

I refer to your letter of 4th February 2014 and accompanying scoping report in which you request an EIA scoping opinion for the above proposed development.

Having regard to Regulation 2(1) and Schedule 4 of The Town and Country Planning (Environmental Impact Assessment) Regulations 2011, the County Council's scoping opinion on the information to be included in an Environmental Statement (ES) is that identified in your letter and accompanying scoping report subject to the recommendations made by consultees and the matters set out below.

Consultations

As required by regulation 13(4) of The Town and Country Planning (Environmental Impact Assessment) Regulations 2011, the following bodies were consulted

- Fylde Borough Council
- LCC Highways Authority
- Highways Agency
- National Grid
- Environment Agency
- United Utilities
- Natural England
- Public Health England

Steve Browne • Interim Executive Director for the Environment
Development Management • Environment Directorate
PO Box 100 • County Hall • Preston • PR1 0LD

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- Location
- Geology
  - Geological prognosis (vertical).
  - Formation tops
- Well pad and access track
  - Construction and design parameters
  - Waste arisings
- Monitoring systems
  - Surface array / Buried array
  - Groundwater monitoring wells
- Well design
- Drilling
  - Drilling details
  - Drilling muds waste
- Hydraulic Fracturing
  - General parameters / waste water arisings
- Initial flow testing
  - General parameters / waste water arisings
- Extended flow testing
  - General parameters / waste water arisings
- Decommissioning and restoration
- Equipment and facilities specifications
- Other parameters
- Durations

Cuadrilla Elswick Ltd
Temporary Shale Gas Exploration
Roseacre Wood, Lancashire

Environmental Statement
Appendix B – Scheme Parameters

RW_ES_Vol2_Appndx B_Scheme Parameters
June 2014

- Forecast Gas composition (Preese Hall analysis)
  - C1= 96.4% (methane)
  - C2 to C5= 1.6% (propane to pentane)
  - C6+ = <0.1% (other hydrocarbons)
  - N2= 1.6%
  - CO2= <1%
  - H2S= 0
  - H2=0

Indicative enclosed flare stack to be used in initial flow testing

- **Baseline**
  - 10km radius around Site.
  - Information: Defra / LA'S.
- **Assess pollutants from:**
  - Construction, operations, equipment and traffic;
  - Flaring including NOx, benzene and NORM.
  - Fugitive emissions.
- **Principal findings**
  - Main emissions during IFT when natural gas is burned in the flare.
  - Enclosed flares: not venting from tanks or lagoons.
  - Significantly below air quality limits in UK/EU.
  - Reuse of flowback within hydraulic fracturing fluid to reduce HGV movements

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There would be potential for effects on air quality associated with vehicle emissions from plant and equipment and flare emissions.

Effects

- All effects would be not significant.

Further mitigation

- Monitor dust generation during the excavation of topsoil and subsoil and the construction of the earth bunds.
- Provide contact details for anybody being affected by dust generation from the Project to raise concerns.
- If there is a dust generation issue, implement best practicable means to control the source of emission or mitigate the effect.

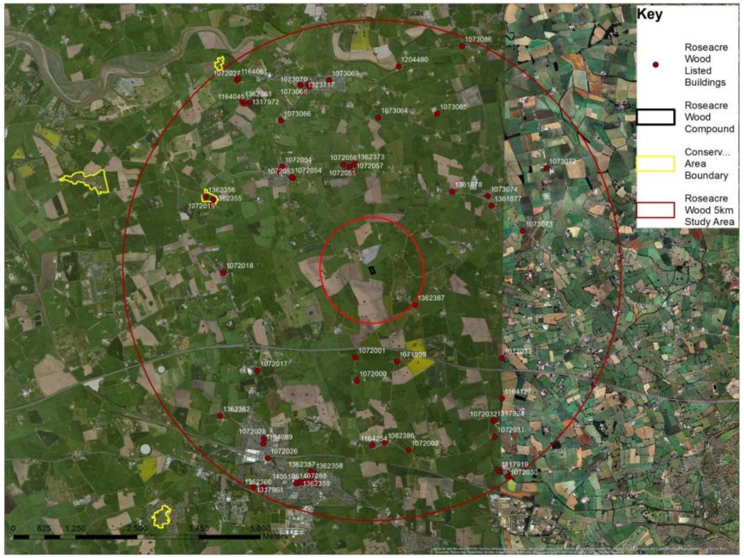
Residual significance

- **Not significant**

The ES concluded that the Project will **not result in a significant effect** on air quality.

- No World Heritage Sites, Scheduled Monuments, Registered Parks, Gardens or Battlefields, Listed Buildings or Conservation Areas. No archaeological finds.
- Potential on archaeology - construction of well pad, access track & gas connection. Mitigate by recording evidence of the track and field systems during excavation.
- No indirect visual impacts on more distant heritage assets.
- No combined impact.

1839 Tithe Map



Listed Buildings and Conservation Areas in 5km Search Area

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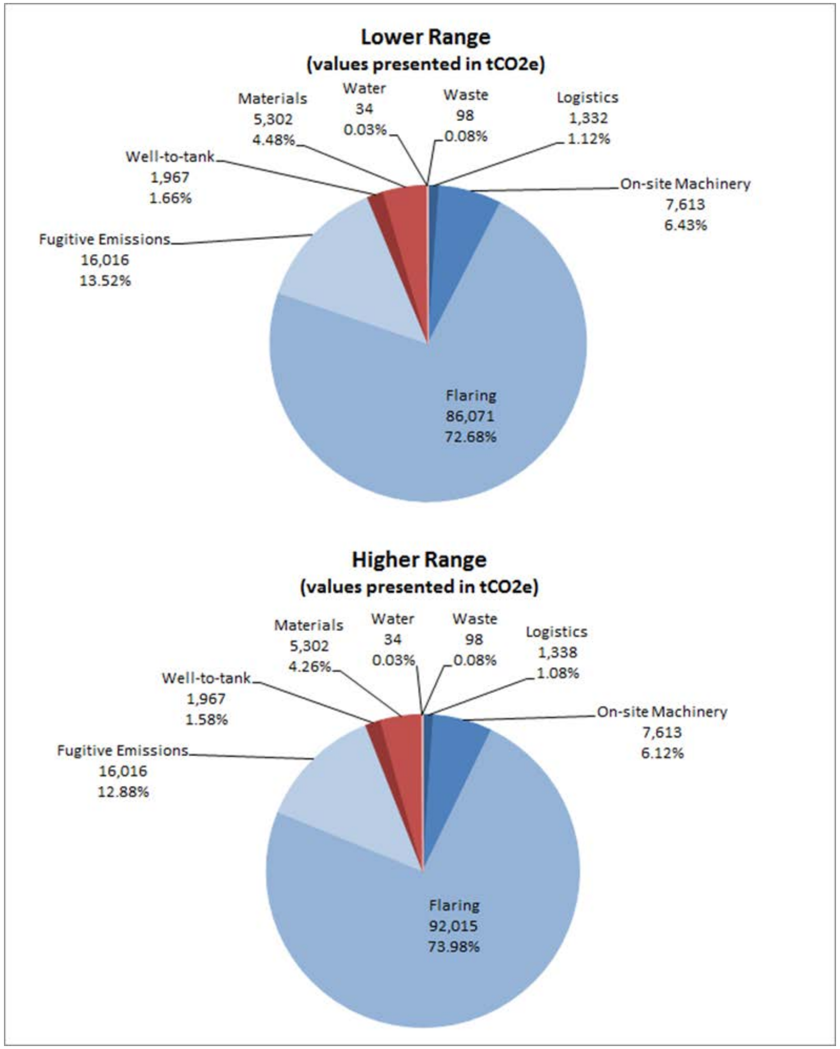
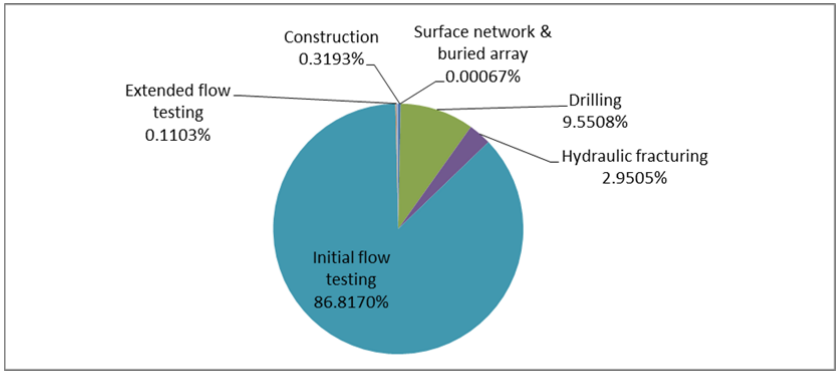
		Direct emissions					Indirect or embedded emissions					
		Logistics		Site emissions			Well-to-tank (WTT) of fossil fuel	Materials	Water		Waste	
		Transportation	Staff travel	On-site machinery	Flaring	Fugitive emissions			Process	Welfare	Waste water	Solid waste
		Transportation of materials, machinery and waste to and from site.	Staff and visitors travelling to and from site.	Such as diesel engines used for drilling, hydraulic fracturing and on-site electricity generation.	The flaring of natural gas including methane emissions resulting from incomplete combustion.	Unintentional releases of gas.	Emissions associated with the production of fuel (petrol / diesel) that is used on the Project.	The production of materials used in the Project, including granular fill, drilling mud, cement, steel casing, sand and chemicals.	Water used in the Project, supplied through mains water system.	Water used for on-site welfare, supplied through mains water system.	The treatment of waste water resulting from the Project.	The treatment of solid waste including inert, non-hazardous and hazardous waste.
On-site	Construction	✓	✓	✓			✓	✓		**	**	✓
	Drilling	✓	✓	✓			✓	✓	✓	✓	✓	✓
	Hydraulic fracturing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Initial flow testing	✓	✓	✓	✓	✓	✓			✓	✓	✓
	Extended flow testing	✓	✓	✓	*	✓	✓			**	**	✓
	Decommissioning and restoration	✓	✓	✓			✓			**	**	✓
Off-site	Installation of surface network & buried array	✓	✓	✓						**	**	✓



Percentage GHG emissions by source for the entire Project



GHG emissions by Project stage

- No significance methodology. Compared to UK national GHG emissions.
- 73% from flare. Total - 118,419 to 124,369 tCO_2e. 0.002% of UK Carbon Budget - negligible. Conservative assessment.

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- Rural farming area. Small population - high economic activity and employment.
- Temporary but beneficial:
  - Direct, indirect and induced local jobs (11 net Direct);
  - Opportunities for local businesses to provide services;
  - Expenditure in local hotels and restaurants by project staff;
  - Community benefit payments for each well hydraulically fractured.
- Risk of crime & public safety low. Effective local police force.

Assessment area	Assessment objective
Employment	Assess the extent to which employment creation is maximised.
Wider economic effects	Assess the ways that economic effects occur, relating outcomes to specific aspects of the project.
Public access and recreational amenity	Assess how costs in this area can be minimised, and benefits maximised.
Crime and Public Safety	Assess how costs in this area can be minimised, and benefits maximised.

Due to the temporary and relatively small scale nature of both Projects the ES concluded that it **will not result in a significant** effect on communities or socio-economic factors.

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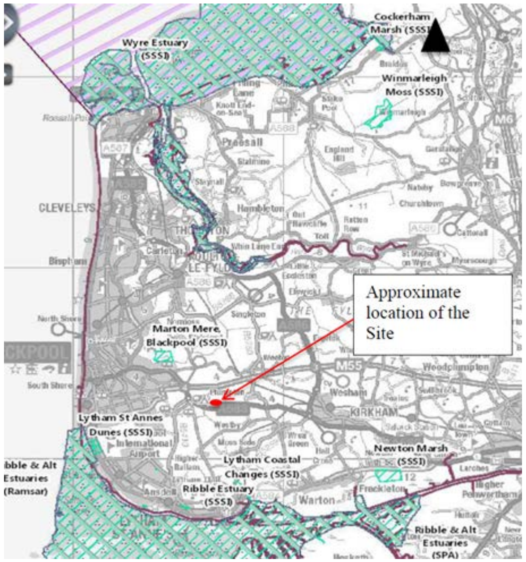
- Identified ecological features of value in zone of influence of the Sites and the arrays.
  - Desk based study
  - Field Surveys
- Ecology Impact Assessment: Institute of Ecology and Environmental Management



Location of Statutory Nature Conservation Site in relation to PNR Site

RW- pond to south of proposed development site field

- Embedded Mitigation:
  - Locating seismometer array points away from areas used by wintering birds
  - Direct visual disturbances will be minimised by security fencing surrounding the Site.

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Effects

- Loss of habitat
- Disturbance due to increase noise levels, vehicle and personnel movements (visual) and increased light levels.
- Alteration of bat behaviour due to heat emitted by the flare stack
- Accidental injury of killing of brown hare

- Effects would be **significant**

Further mitigation

- Avoid installation of the monitoring array during the winter period for the 3 sites adjacent to Lytham Moss BHS and the fields of the 13 other stations which support wintering birds (PNR array only)
- Measures to reduce the magnitude of lighting impacts on feeding bats
- Replace any lost hedgerows and trees
- Vegetation clearance to occur outside of bird breeding season or following confirmation that there are no breeding birds using the vegetation for nesting prior to its removal
- Qualified ecologist will undertake pre-start checks
- Noise attenuation measures

Residual significance

- **Not Significant**

The ES concluded that the Project will **not result in a significant effect** on ecological features.

Hydrogeology and ground gas – Assessment

Assessment considers possible impacts:

- Well pad activities and materials in transit
- Well construction and integrity
- Fractures created by hydraulic fracturing

Environmental Agency Groundwater Source Protection Zones

Baseline

- Desk study research
- Site reconnaissance visit
- Additional data gathering is also planned

Approach:

- Identification of hazards and potential source-pathway-receptor linkages
- Estimation of the probability of the risk being realised
- Identification of consequences
- Estimation of the magnitude of the risk
- Identification of the risk management options (‘mitigation measures’)
- Estimation of residual risk

Relevant receptors include:

Groundwater, surface water and supported ecology, off-site human health, on-site human health, and crops and livestock.

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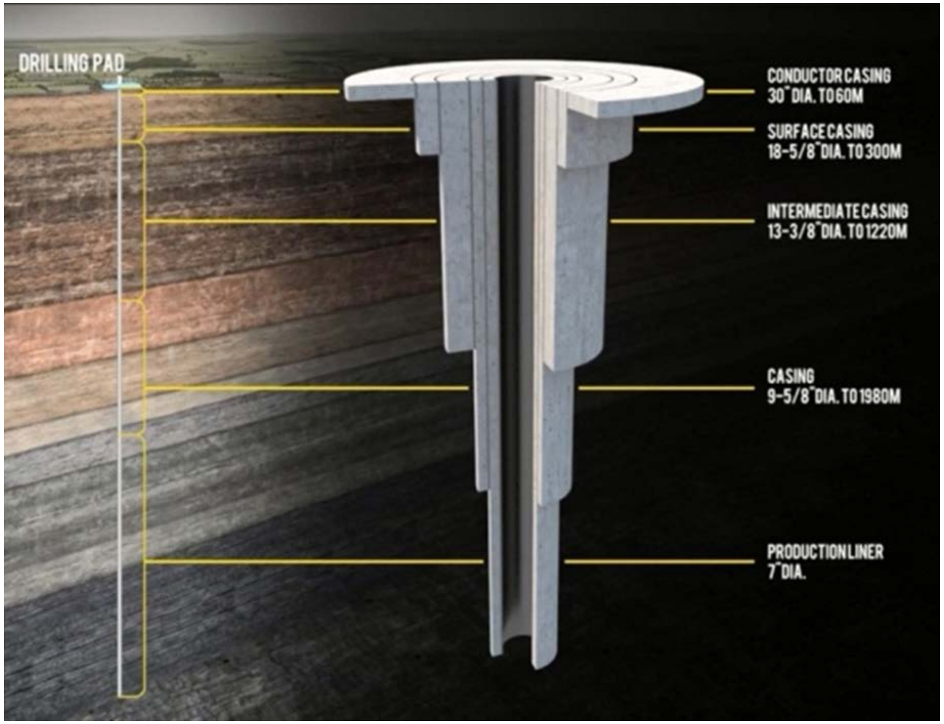
- Design and management of wells & operations to ensure no pollutants released to surface or groundwater.
- Wells: drilled, constructed and tested iaw regulation / industry guidance.
- Wells: min 2-barrier cement-sealed.
- Drilling fluids: non-hazardous used for drilling in sensitive rock layers.
- Hydraulic fracturing: accord with industry guidance / regulation.
- Fracturing fluids used: non-hazardous to groundwater.
- Fracture growth monitored.
- Water quality monitored.
- Wells decommissioned and restored iaw regulation / industry guidance.



- Hydraulic fracturing fluid:
  - Water and sand (99.95% by vol)
  - Polyacralamide friction reducer (0.05%)
  - Dilute hydrochloric acid (10% acid, 90% water) may be used as a spear head.

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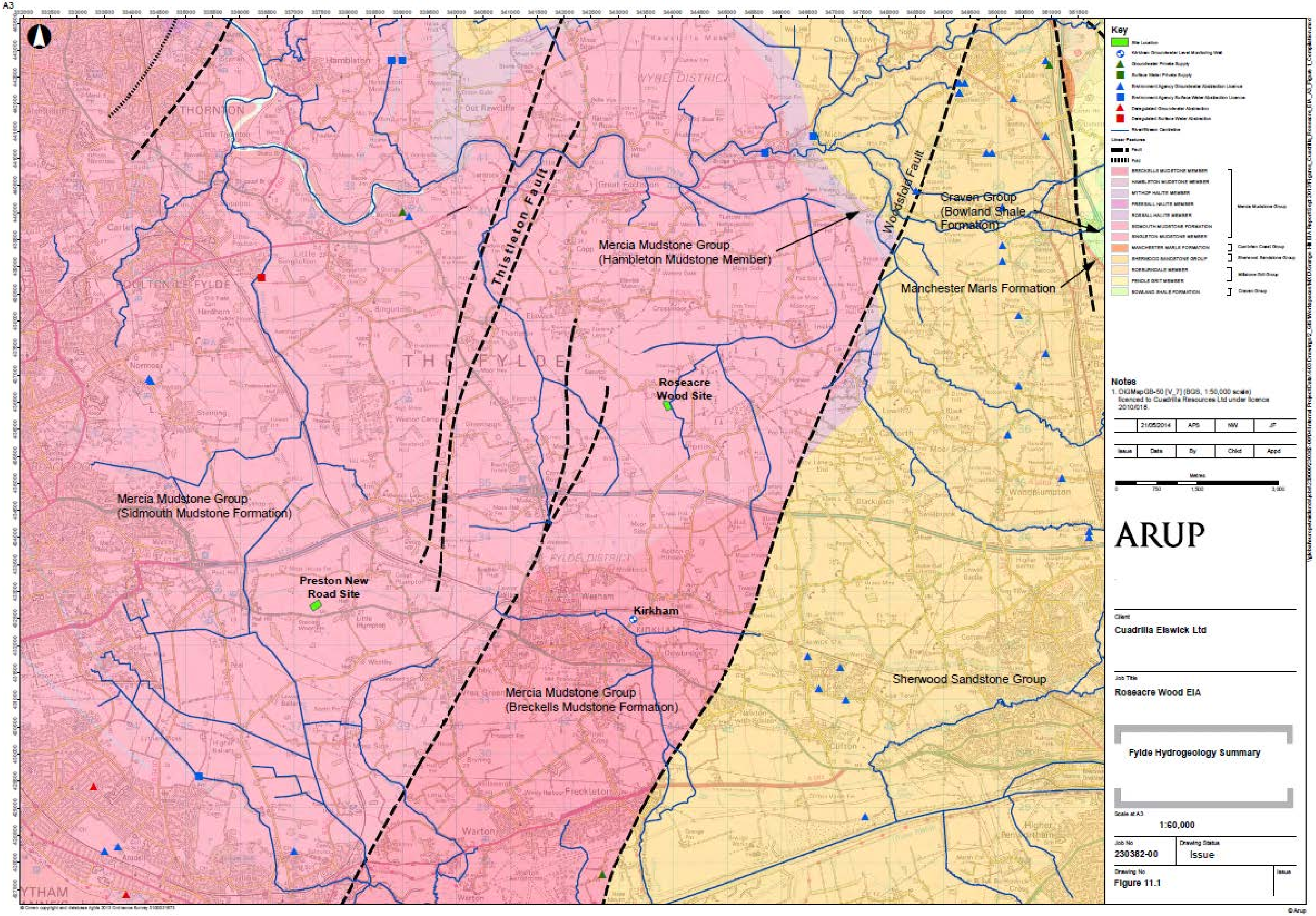
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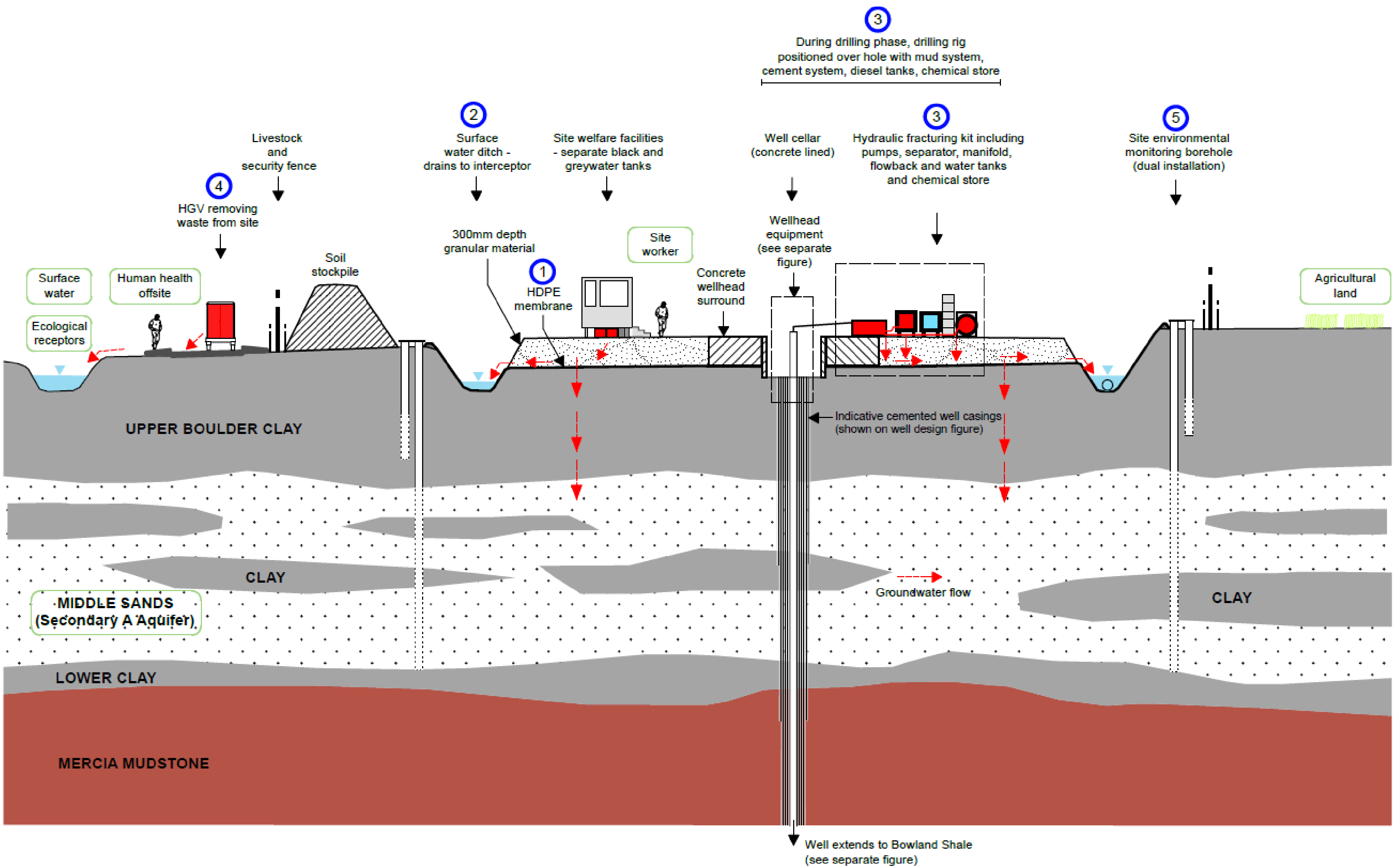
Key
Notes
Mercia Mudstone Group
(Hambleton Mudstone Member)
Craven Group
(Bowland Shale
Formation)
Woodsfold Fault
Thistleton Fault
Manchester Marls Formation
Roseacre
Wood Site
Mercia Mudstone Group
(Sidmouth Mudstone Formation)
Preston New
Road Site
Kirkham
Mercia Mudstone Group
(Breckells Mudstone Formation)
Sherwood Sandstone Group
THE FYLDE
ARUP
Client
Cuadrilla Elswick Ltd
Job Title
Roseacre Wood EIA
Fylde Hydrogeology Summary
Scale at A3
1:60,000
Job No
230362-00
Drawing Status
Issue
Drawing No
Figure 11.1



Conceptual Model of Well Pad

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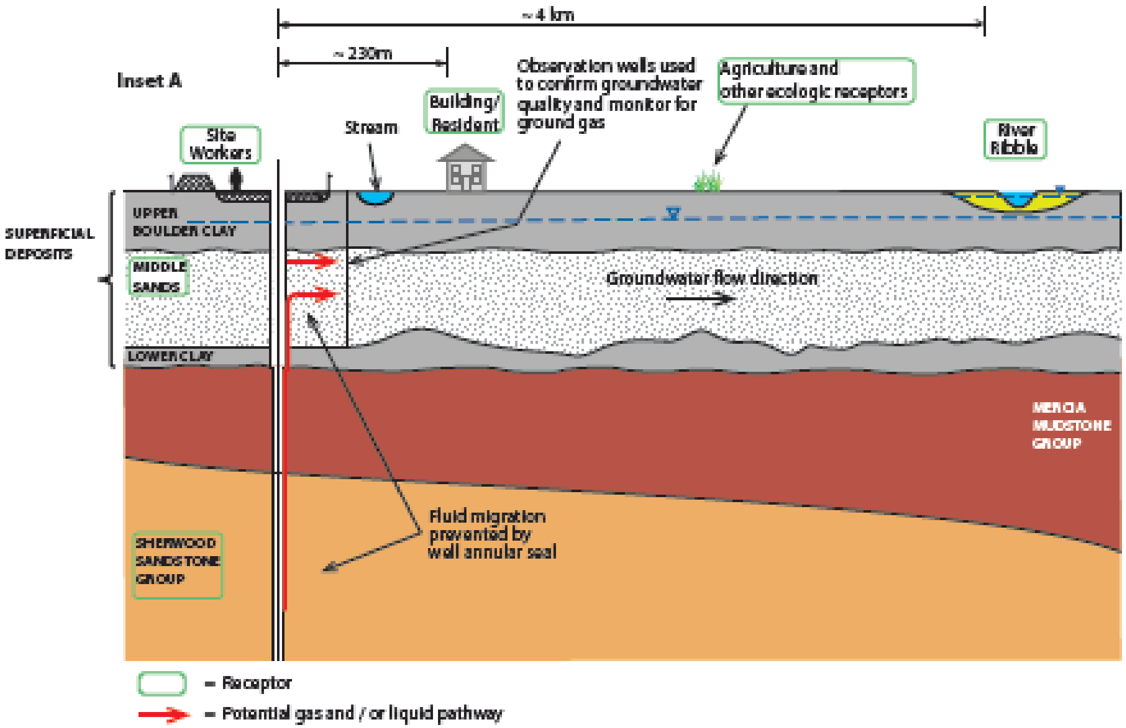

Notes:

- Liquids include fracture fluid, formation water and flowback fluid.
- Gas includes formation gas (such as methane) from Collyhurst Sandstone, Bowland Shale and Hodder Mudstone. Note that no sulphur containing gases have been detected such as hydrogen sulphide.
- Exact lateral location may be constructed at any depth within the Bowland Shale, such that induced fractures remain within the Bowland Shale (approximately between 1,900 and 2,900m)
- Up to 4 J-shaped wells to be installed at the Site. Only the first well will include a vertical pilot hole.

 Potential Pollution Linkages: Well Integrity

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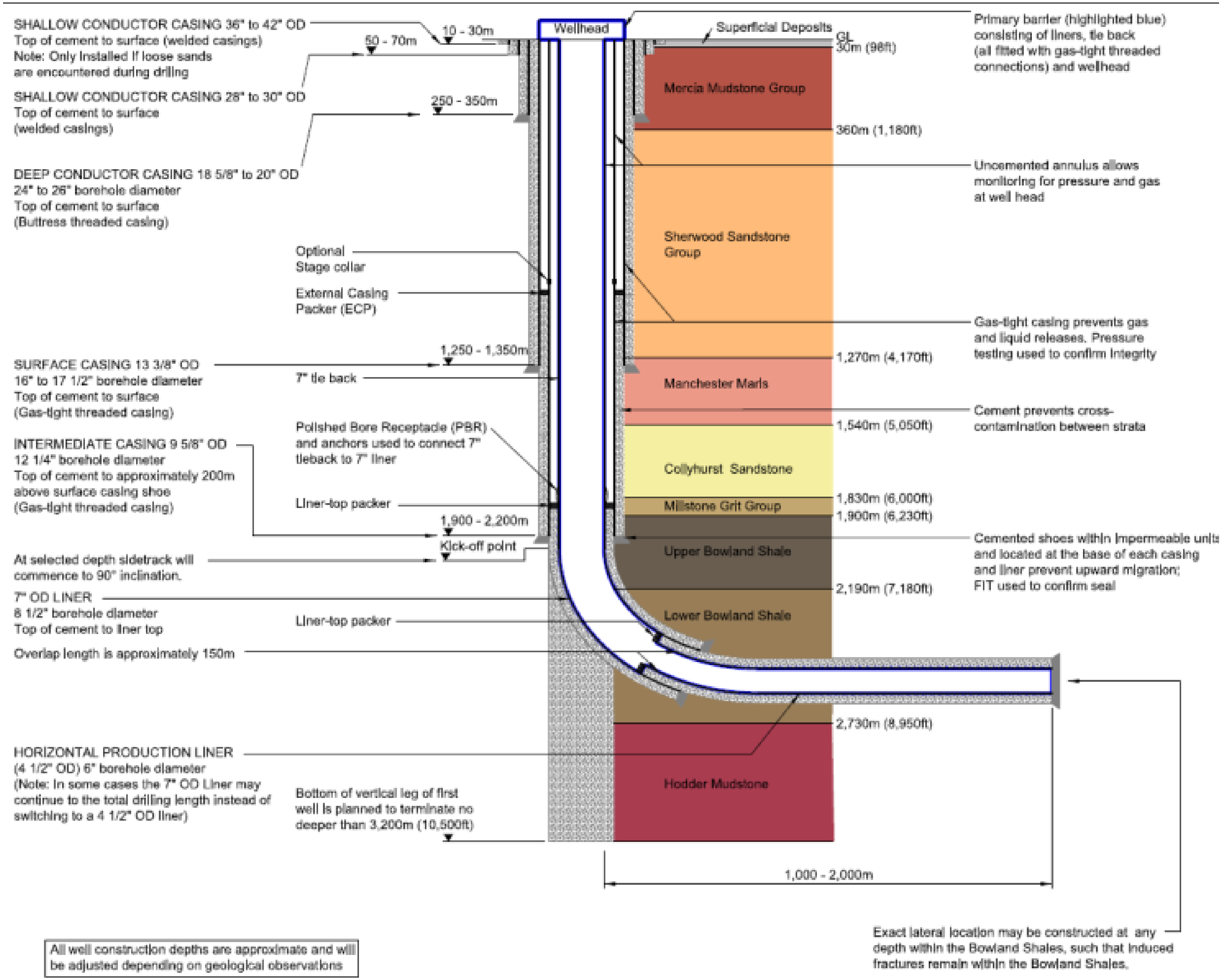
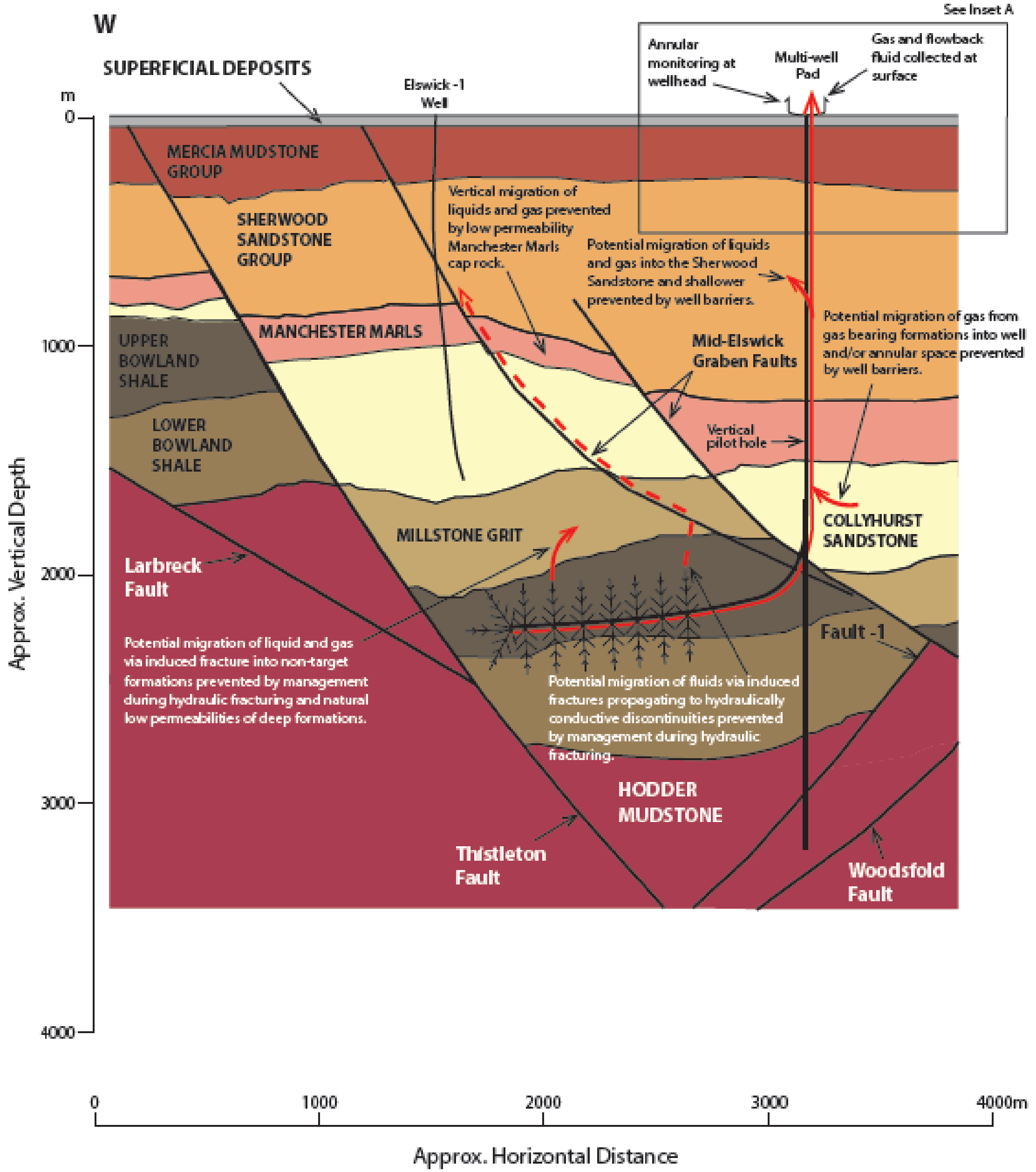

SHALLOW CONDUCTOR CASING 36" to 42" OD
Top of cement to surface (welded casings)
Note: Only installed if loose sands
are encountered during drilling
SHALLOW CONDUCTOR CASING 28" to 30" OD
Top of cement to surface
(welded casings)
DEEP CONDUCTOR CASING 18 5/8" to 20" OD
24" to 26" borehole diameter
Top of cement to surface
(Buttress threaded casing)
Optional
Stage collar
External Casing
Packer (ECP)
SURFACE CASING 13 3/8" OD
16" to 17 1/2" borehole diameter
Top of cement to surface
(Gas-tight threaded casing)
7" tie back
Polished Bore Receptacle (PBR)
and anchors used to connect 7"
tieback to 7" liner
INTERMEDIATE CASING 9 5/8" OD
12 1/4" borehole diameter
Top of cement to approximately 200m
above surface casing shoe
(Gas-tight threaded casing)
Liner-top packer
At selected depth sidetrack will
commence to 90° inclination.
7" OD LINER
8 1/2" borehole diameter
Top of cement to liner top
Liner-top packer
Overlap length is approximately 150m
HORIZONTAL PRODUCTION LINER
(4 1/2" OD) 6" borehole diameter
(Note: In some cases the 7" OD Liner may
continue to the total drilling length instead of
switching to a 4 1/2" OD liner)
Bottom of vertical leg of first
well is planned to terminate no
deeper than 3,200m (10,500ft)
10 - 30m
50 - 70m
250 - 350m
1,250 - 1,350m
1,900 - 2,200m
Kick-off point
Wellhead
Superficial Deposits
GL
30m (98ft)
Mercia Mudstone Group
360m (1,180ft)
Sherwood Sandstone
Group
1,270m (4,170ft)
Manchester Marls
1,540m (5,050ft)
Collyhurst Sandstone
1,830m (6,000ft)
Millstone Grit Group
1,900m (6,230ft)
Upper Bowland Shale
2,190m (7,180ft)
Lower Bowland Shale
2,730m (8,950ft)
Hodder Mudstone
1,000 - 2,000m
Primary barrier (highlighted blue)
consisting of liners, tie back
(all fitted with gas-tight threaded
connections) and wellhead
Uncemented annulus allows
monitoring for pressure and gas
at well head
Gas-tight casing prevents gas
and liquid releases. Pressure
testing used to confirm integrity
Cement prevents cross-
contamination between strata
Cemented shoes within impermeable units
and located at the base of each casing
and liner prevent upward migration;
FIT used to confirm seal
Exact lateral location may be constructed at any
depth within the Bowland Shales, such that induced
fractures remain within the Bowland Shales.
All well construction depths are approximate and will
be adjusted depending on geological observations



Potential Pollution Linkages: Induced Fractures

Effects

- Potential hydrogeology and ground gas effects would be associated with leaks or spills entering the wider environment (the soil above the wells, groundwater, surface water or the atmosphere) leading to pollution or contamination.
- The risk associated with each S-P-R linkage is assessed to be **low.**

Further mitigation

- No further mitigation proposed.

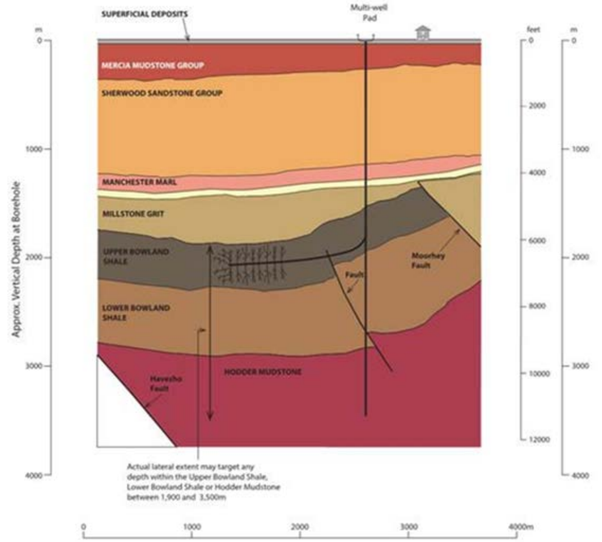
Residual significance

- As no additional mitigation other to those that are embedded are necessary, the residual risk magnitudes are also assessed to be **low and non- significant.**

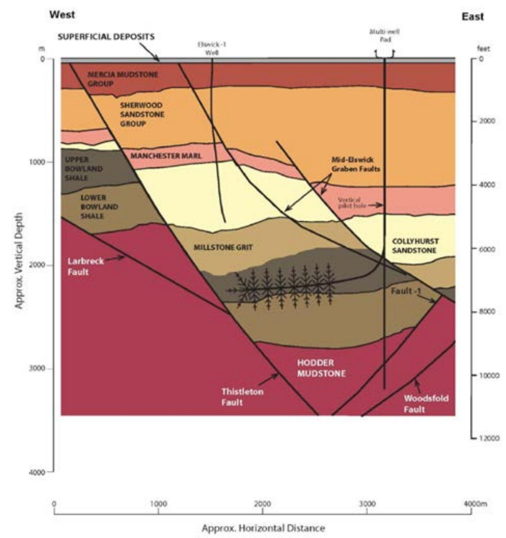
The ES concluded that the Project will **not result in a significant effect** on hydrogeological features.

- Induced Seismicity:
  - Felt effects and potential damage to buildings and infrastructure.
  - Normally during hydraulic fracturing from propagation of engineered fractures, or transmission of fluid pressure into critically stressed fault.

- Embedded mitigation: required by DECC and recommended by UKOOG.
  - Avoid drilling wells into, or close to, existing pre-stressed regional faults
  - Risk based geo-mechanical assessments of proposed hydraulic fracturing with regard to known faults



Preston New Road - 8km west of Woodsfold Fault and 1.5km east west of the Thistleton Fault.



Roseacre Wood- 3km west of Woodsfold Fault and 3km east of the Thistleton Fault.

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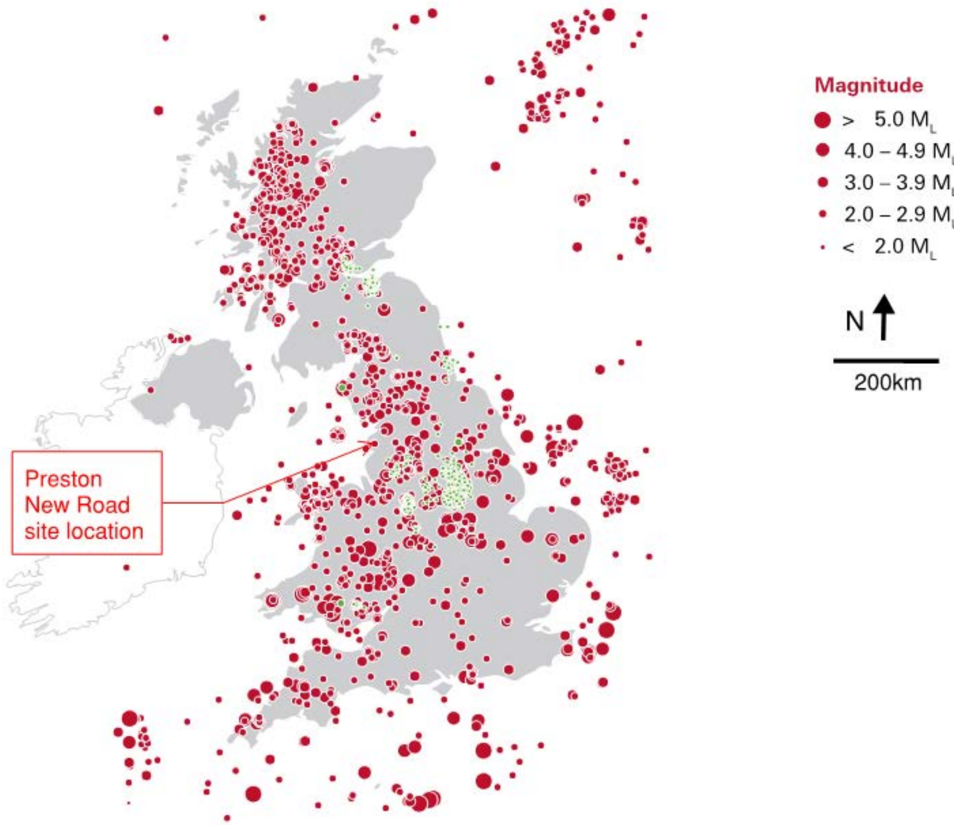
- Monitoring background induced and natural seismicity before, during and after hydraulic fracturing

- Operational mitigation- stepped progressive approach to hydraulic fracturing building up to a maximum pump volume of 765m3

- Reduce the volumes of hydraulic fracturing fluid injected.



Spatial distribution of natural seismicity (red) and coal- mining induced seismicity (green) in the UK from 1382 to 2012

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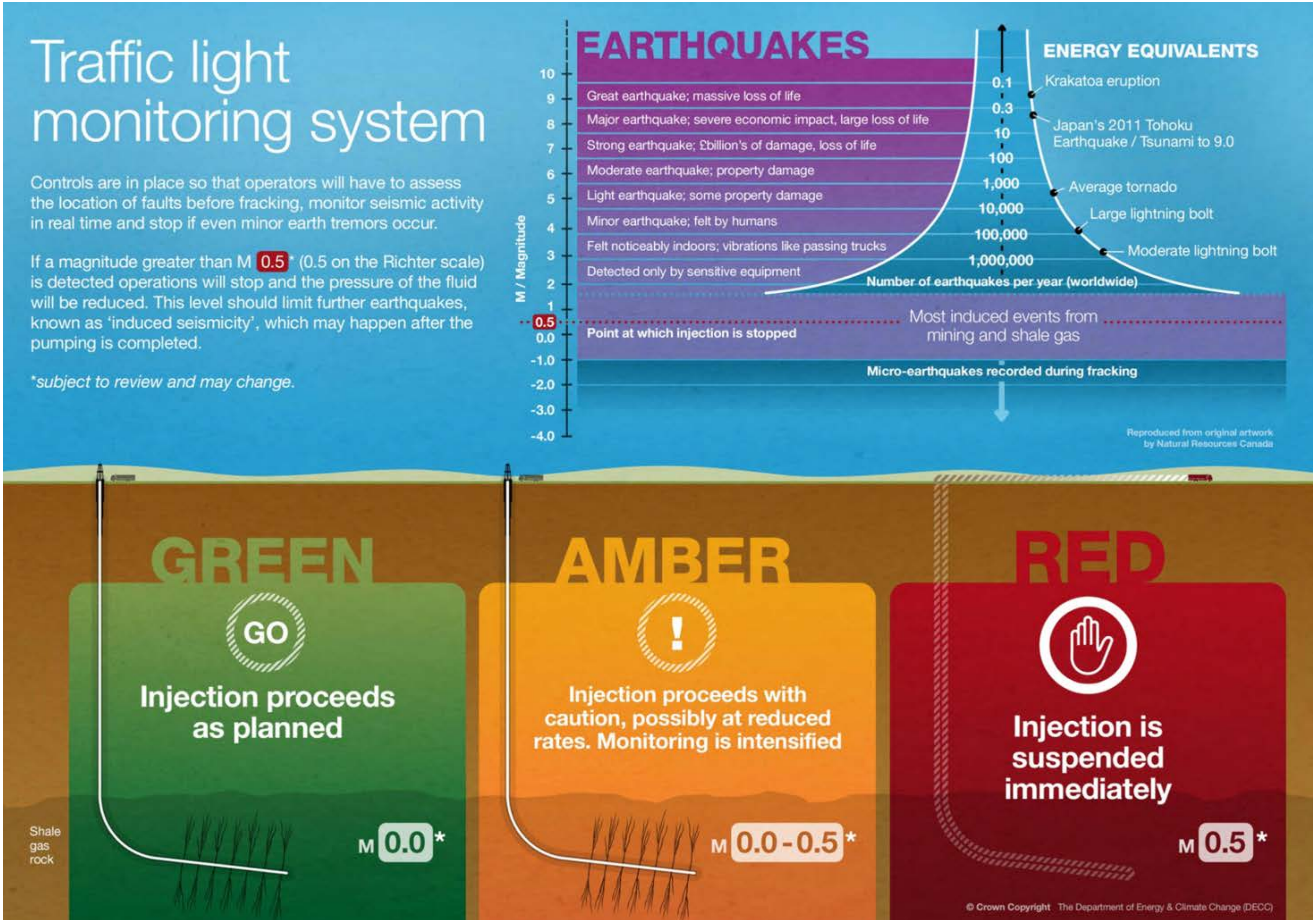
Traffic light monitoring system
Controls are in place so that operators will have to assess the location of faults before fracking, monitor seismic activity in real time and stop if even minor earth tremors occur.
If a magnitude greater than M 0.5* (0.5 on the Richter scale) is detected operations will stop and the pressure of the fluid will be reduced. This level should limit further earthquakes, known as 'induced seismicity', which may happen after the pumping is completed.
*subject to review and may change.
EARTHQUAKES
M / Magnitude
10
9
8
7
6
5
4
3
2
1
0.5
0.0
-1.0
-2.0
-3.0
-4.0
Great earthquake; massive loss of life
Major earthquake; severe economic impact, large loss of life
Strong earthquake; £billion's of damage, loss of life
Moderate earthquake; property damage
Light earthquake; some property damage
Minor earthquake; felt by humans
Felt noticeably indoors; vibrations like passing trucks
Detected only by sensitive equipment
Point at which injection is stopped
Most induced events from mining and shale gas
Micro-earthquakes recorded during fracking
0.1
0.3
10
100
1,000
10,000
100,000
1,000,000
Number of earthquakes per year (worldwide)
ENERGY EQUIVALENTS
Krakatoa eruption
Japan's 2011 Tohoku Earthquake / Tsunami to 9.0
Average tornado
Large lightning bolt
Moderate lightning bolt
Reproduced from original artwork by Natural Resources Canada
GREEN
GO
Injection proceeds as planned
M 0.0*
Shale gas rock
AMBER
!
Injection proceeds with caution, possibly at reduced rates. Monitoring is intensified
M 0.0 - 0.5*
RED
Injection is suspended immediately
M 0.5*
© Crown Copyright The Department of Energy & Climate Change (DECC)

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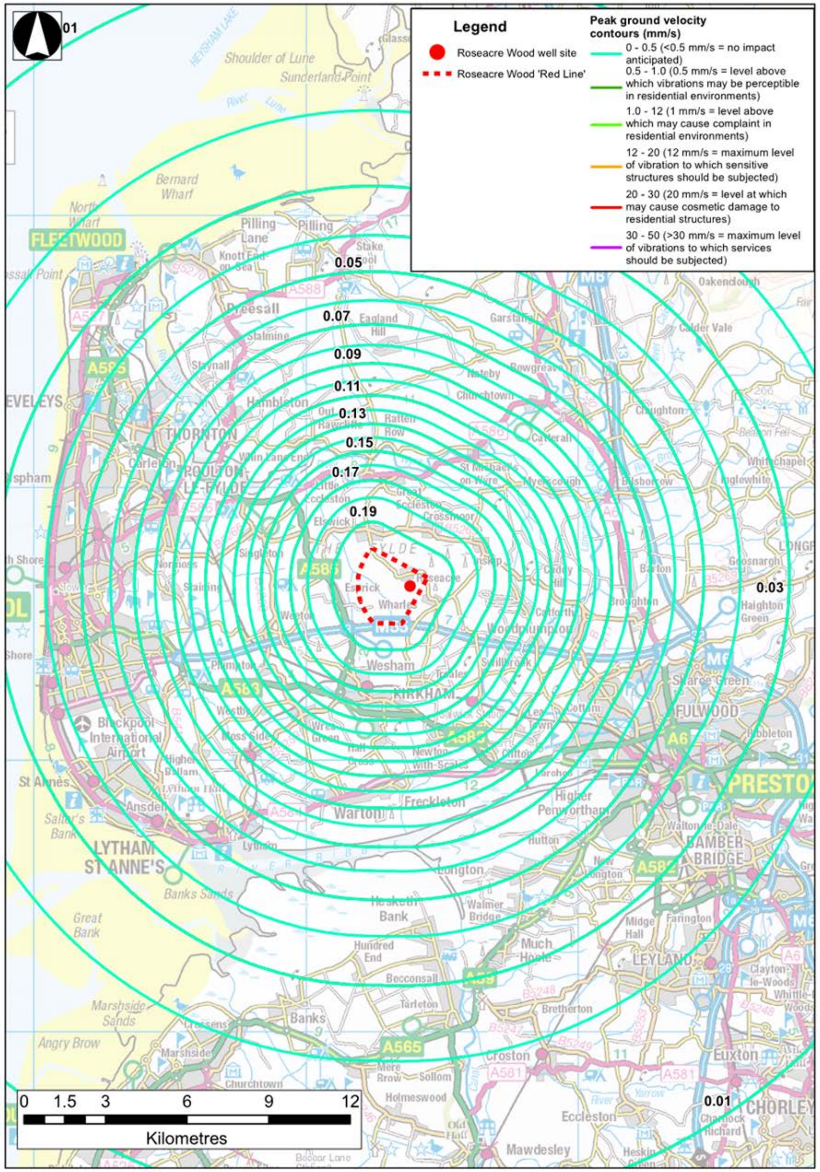
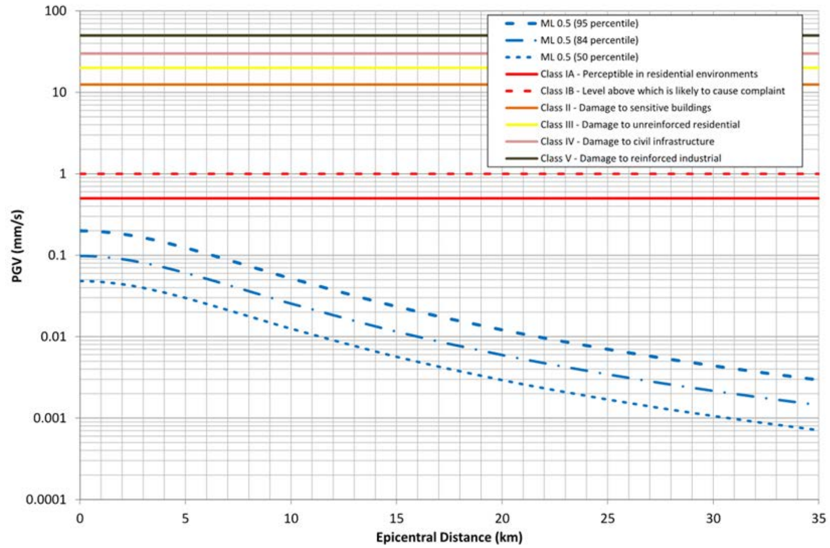
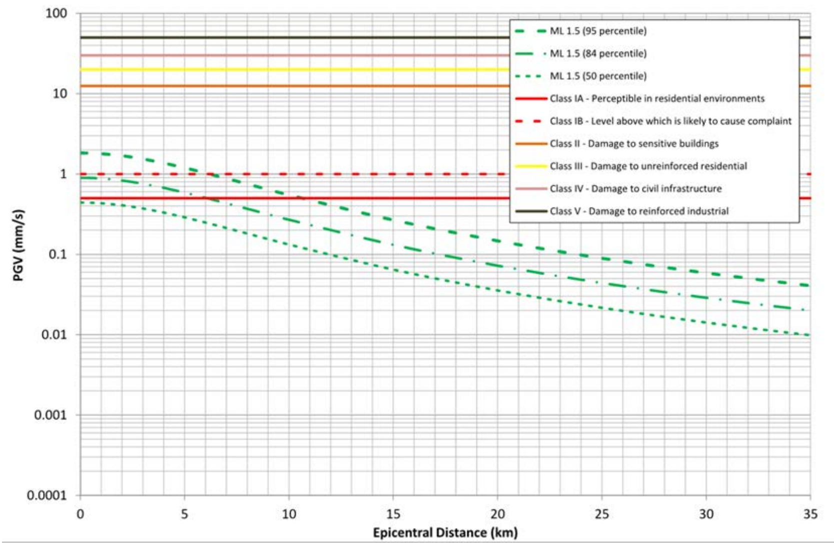
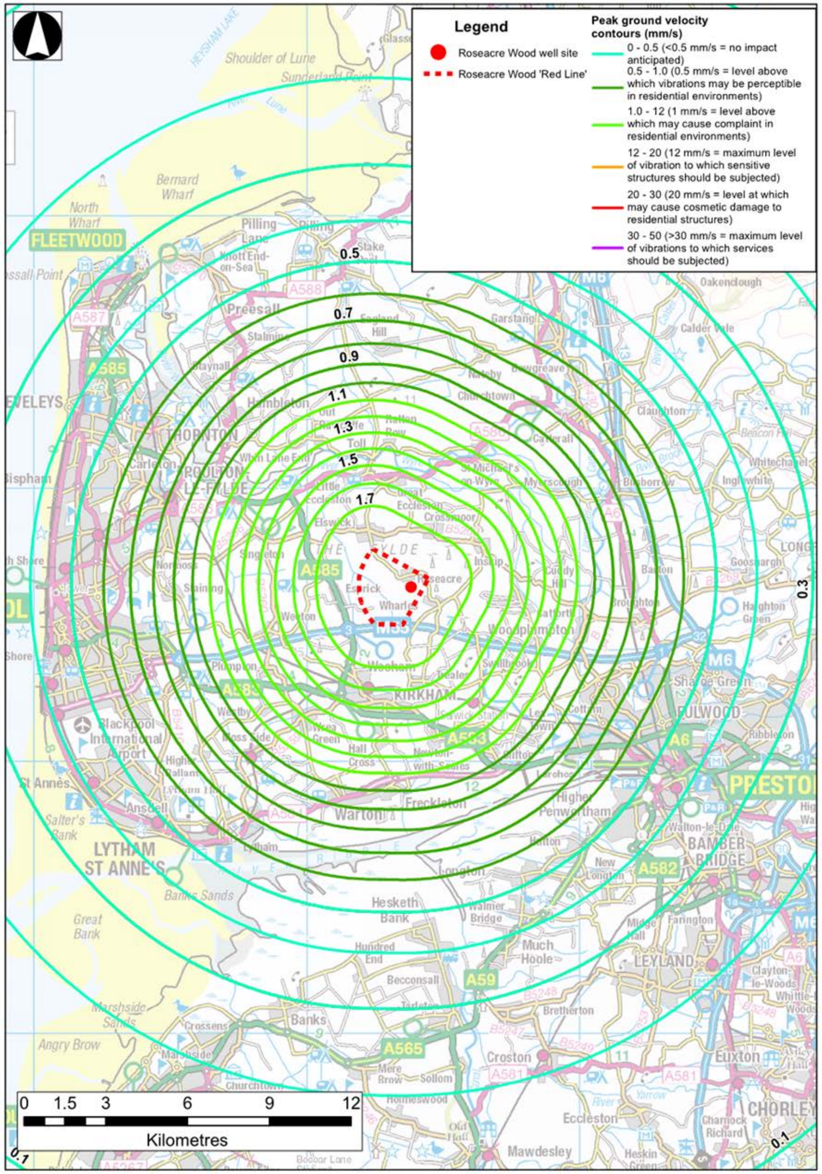




- Scenario 1 (0.5 ML) has been chosen as it represents the 0.5 ML Red light threshold of the Traffic Light System, as recommended by DECC.





- Scenario 2 (1.5 ML) = 0.5 ML Red light of TLS + 1.0 ML trailing effect (post-injection).
- DECC: 1.5 ML typically the limit of felt vibrations - below what may be felt at the ground surface.

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Induced Seismicity

There would be potential for induced seismicity effects associated with ground motion hazard, well integrity, liquefaction, slope instability and cumulative effects of settlement and fluid migration.

Effects

- All effects would be negligible or minor and not significant.

Further mitigation

- None required

Residual significance

- **Not significant**

The ES concluded that the Project will **not result in a significant effect** from induced seismicity.

- Detailed assessment on construction, use and decommissioning of the well pad and access track.
- Moderate agricultural quality, but Clay. Best practice for excavation and handling - residual effects are not significant.
- Effect on farming operations not significant.
- The two Sites are not in same ownership - no cumulative impact on one landowner from both projects.

Description of effect	Significance	Mitigation	Residual effect
Construction, drilling, hydraulic fracturing, initial and extended flow testing decommissioning and restoration.			
Temporary displacement of soil resources	Moderate / Major Significant	Stripped and stored according to Defra best practice.	Negligible Not Significant
Temporary loss of productive agricultural land	Negligible Not Significant	Reinstatement requirement	Negligible Not Significant
Loss of farmable area to the holding affected	Minor Not Significant	Reinstatement requirement	Negligible Not Significant
Cumulative Impacts	Not Applicable.	None – subject to appropriate reinstatement and aftercare of land	Negligible Not Significant

Landscape assessment findings:

- Localised direct change due to development proposals temporary altering a very small proportion of one local character area during construction.
- For all phases of the Project there would be **no significant landscape effects.**

Visual assessment findings:

- **Significant adverse visual effects** during drilling, hydraulic fracturing and flow testing.
- **PNR-** 7 of the principal viewpoints would experience significant adverse effects
- **RW-** 11 of the principal viewpoints would experience significant adverse effects

PNR- indicative night and day views from Preston New Road

RW- indicative night and day views of 53m drilling rig

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Effects

- Landscape- localised direct change – not significant
- Visual Amenity – Some viewpoints significantly adversely affected on both Sites.

Further mitigation

- Landscape bunds
- Planting of native trees, shrubs and hedgerow.
- Lighting to comply with lighting guidance
- Tree survey and root protection
- Minimal working area

Residual significance

- Landscape**- Not significant**
- Visual Amenity- **Significant but temporary (over a two year period)**

The ES concluded that both Projects will **not result in a significant effect** on landscape features.

A **significant but temporary effect** on visual amenity is predicted during the first 2 to 3 years of both Projects - due to the visually intrusive nature of some of the equipment that will be used.

During the installation of the arrays, construction and decommissioning and restoration phases, all effects would be negligible or minor adverse and **not significant.**

Effects

- During the drilling, hydraulic fracturing, initial flow testing and extended flow testing, all effects would be **major adverse and significant.**

Further mitigation

- Follow industry best practice for the arrangement of lighting
- Covers to prevent light spill
- Low powered lighting to illuminate other areas of the Site that require lighting.
- Low key security lighting

Residual significance

- Effect of skyglow and building luminance is **significant** (however magnitude of impact reduced to moderate adverse)
- Effect of light spill beyond site boundary and light source intensity is reduced to **minor adverse and not significant.**

The ES concluded that the effects of lighting being directed towards windows and light intensity would **not result in a significant effect** once the mitigation measures are implemented.

The magnitude of the skyglow and building luminance effects would be reduced through the mitigation measures, although the **effects would remain significant (but temporary).**

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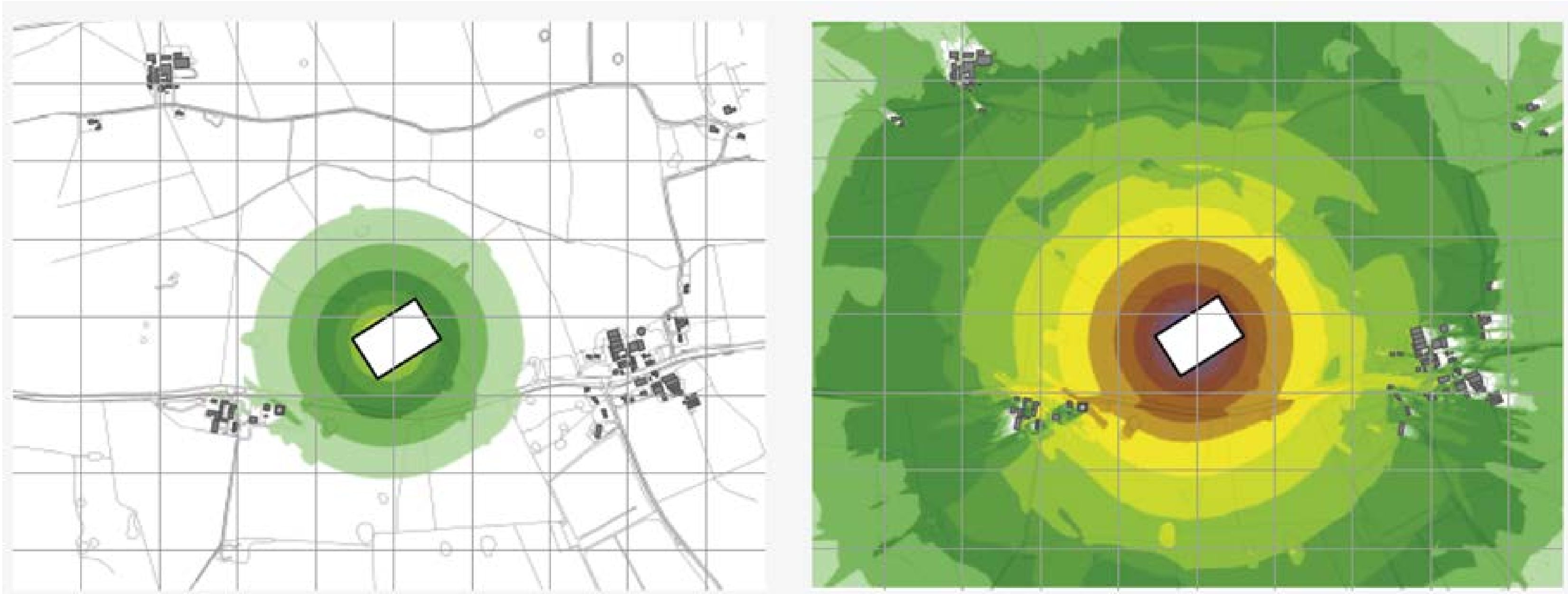
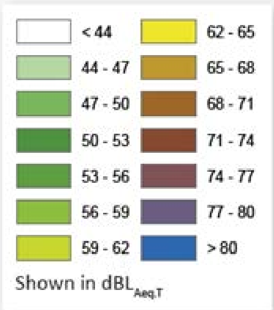


- Significant Effect: Hydraulic fracturing pumping (night-time, weekends)
- Only operate during weekday daytime and Saturday mornings
- Residual impact not significant.



Key Terms

dB = Decibel, a unit to measure sound levels.

L_{Aeq} – Measure used for the assessment of overall noise exposure (equivalent continuous sound level)

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Concerns about how flowback fluid would be treated and disposed.

Concerns about the disposal of surface water and any other types of waste.

Comments about the treatment of waste generated and how it will be transported from the Site.

Concerns about the low levels of Naturally Occurring Radioactive Materials (NORM) being present in the waste generated.

- Flowback fluid:
  - Hydraulic fracturing fluid
  - Gas or other hydrocarbons
  - Formation water
  - Minerals leached from shale rock
  - Naturally occurring radioactive materials (NORM)
  - Possibly residual drilling fluid.

- Embedded Mitigation:
  - Compliance with permitting requirements for waste.
  - Reduced volume flowback fluid.
  - Surface water collected in pre-prepared channels & disposed.
  - Licenced waste operators confirmed safe disposal of waste

Waste Stream	Disposal
Polymer Based Water Drilling Muds	Removed by licensed waste to permitted treatment facility in accordance with published guidance
Drill Cuttings associated with Polymer Based Water Drilling Muds	Separated for recycling recycled into secondary aggregate at permitted waste management facility.
Drill Cuttings associated with LTOBM	Drill cuttings contaminated with LTOBM will be classified as hazardous waste and disposed offsite at licensed waste sites.
Losses to formation	Drilling fluids designed to minimise loss to the adjacent formations, although possible some small losses will occur. Seek to minimise such losses. When drilling through sensitive groundwater receptors no hazardous chemicals will be used. Unlikely to recover losses to formation.
Cement	Returning cement cannot be re-used on site. Due to the small quantities the cement can be sent for recycling to an offsite authorised waste facility.
General waste- paper, timber, scrap-metal	General waste recycled onsite where feasible before being sent to a Materials Recovery Facility to maximise waste diverted from landfill.
Rainfall runoff	Rainfall runoff is tankered offsite and treated at a local WwTW.
Foul effluent	Foul effluent is tankered offsite and treated at a local WwTW.

Waste Stream	Disposal
Flowback Fluid	Proportion (40%) of injected Fracturing fluid (water and sand 99.95%, polyacrylamide 0.05%) is extractive waste. NORM (>1Bq/l) = radioactive waste. Stored in flowback tanks for measurement and storage until it is removed for re-use. Some re-used in hydraulic fracturing. Separating process to remove sands/floating oil/gas. Apply UV disinfection. No chemical treatment onsite. Remaining flowback to licensed treatment facility.
Sand	Sand from fracturing fluid removed in the 4 stage separator process that separates any natural gas extracted. Stored in sand bin; removed for treatment/disposal. Recycled - secondary aggregates.
Surplus natural gas	Flared.
Solid scale	Occasional treatment/disposal required. Insoluble barium, calcium and strontium compounds, maybe radium. Quantitative lab analysis. Disposal in sealed landfill cells, in accordance with the operator's environmental permit(s).
Equipment contaminated by NORM	Specialist treatment facilities.
Materials contaminated by NORM	Specialist treatment facilities.

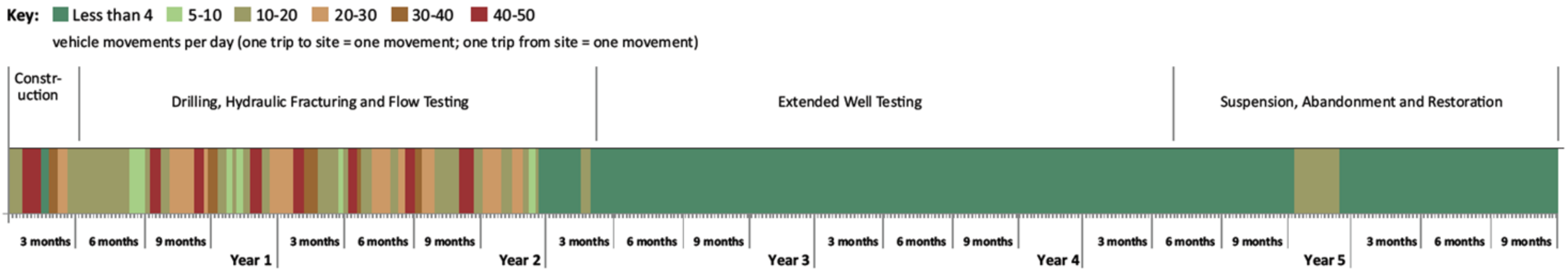
Site	Daily			Weekly		
	Tonnes	m3	Litres	Tonnes	m3	Litres
Treatment Site A	300	300	300,000	2,100	2,100	2,100,000
Treatment Site B	120	120	120,000	600	600	600,000
Total Capacity	420	420	420,000	2,700	2,700	2,700,000

Physical capacity of flowback fluid treatment facilities

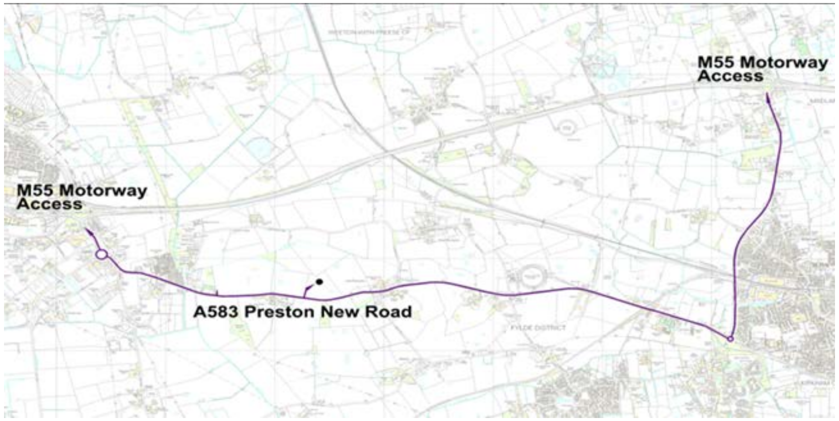
Maximum Weekly Flowback Fluid (m3)	Weekly Treatment Capacity (m3)	%Treatment Capacity
1,750	2,700	65

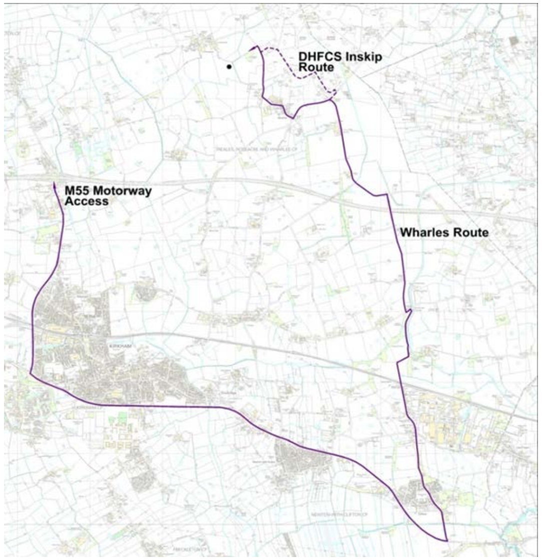
Maximum weekly flowback fluid treatment capacity during flow testing

- General waste , inert waste and non-hazardous waste will not result in a significant effect.
- Quantity of waste generated by the Project will not result in a significant effect. – there is sufficient capacity to treat the waste generated by the Project.
- Although there is sufficient capacity to treat flow- back fluid , it is still anticipated to result in a significant effect because at peak times it will utilise a major proportion of the available treatment capacity within 100 miles of the Site.



- Vehicle movements vary. Peaks (a few days) when equipment brought to or removed from Site.
- Traffic increase not a significant transport effect.





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There is no embedded mitigation relating to traffic and transport

Effects

- There would be a combination of slight adverse or neutral effects on driver delay, pedestrian delay, pedestrian amenity, severance, accidents and safety, and dust and dirt.
- All effects would be not significant.

Further mitigation

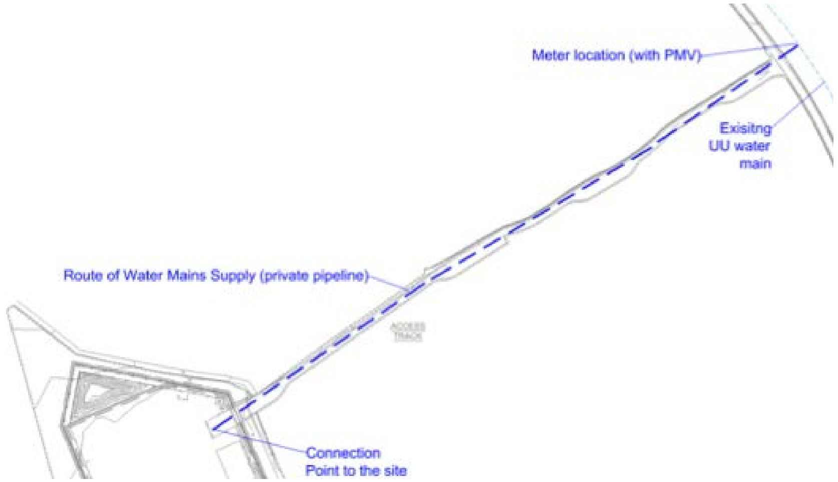
- Traffic Management Plan which could include:
  - Vehicle and route restrictions
  - Site management requirements (sheeting, damping down)
  - Driver training and education
  - Monitoring of routes and traffic flows
  - Periodic reporting to the Highways Authority
  - Feedback mechanism for residents

Residual significance

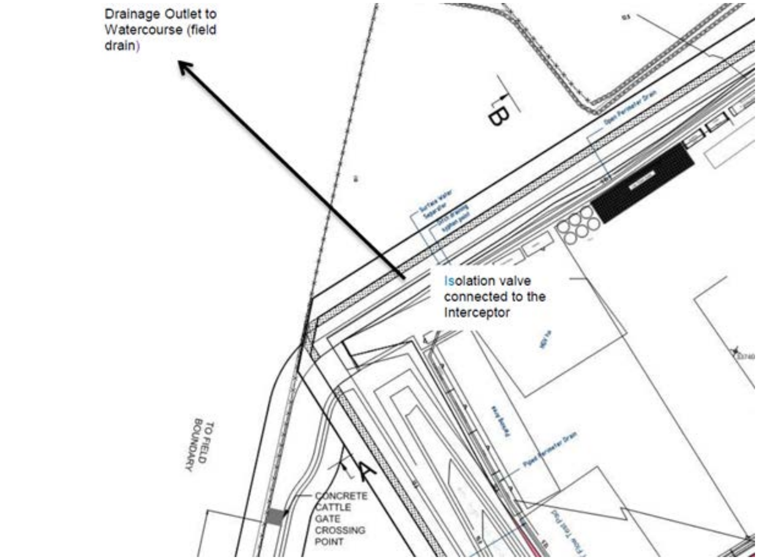
- **Not significant**

The ES concluded that transport impacts **would not result in a significant effect**.

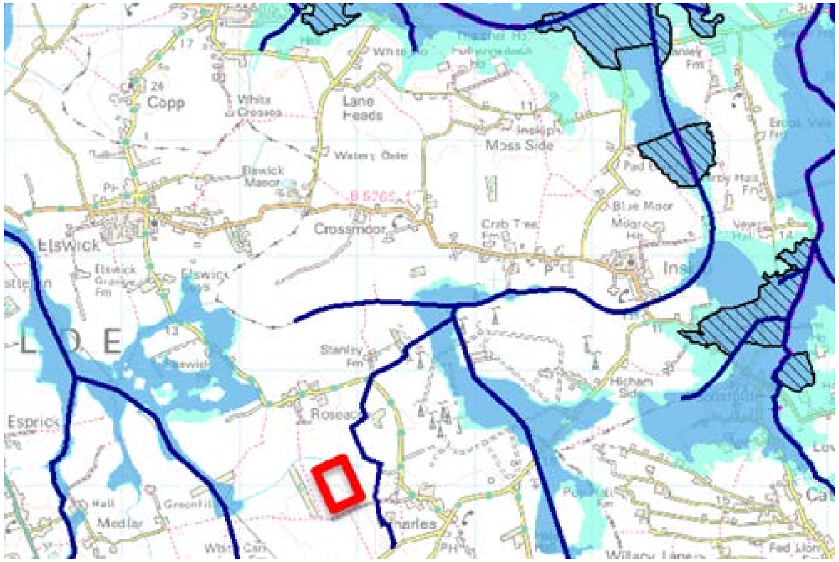
- Assessed:
  - Requirement for water use
  - Surface and drainage impacts
  - Well pad containment and drainage system
  - Flood risk relating to implementation of the Project
- Achieved a 20% reduction in proposed use of mains water by:
  - Reducing the volume of water used for hydraulic fracturing.
  - Re-using flow back fluid.
- Water supply requirements
  - 112,000m3 during 150 stages of hf, incl mini-frac for each stage (no flowback reuse).
  - 89,500m3 during 150 stages of hf, incl minifrac for each stage (flowback reuse).
- Local water supplier can meet the demand.



RW: Water Pipeline Supply Route



PNR - Site drainage connections to adjacent field drainage



Flood zones relative to the Well Pad - RW

- Sufficient capacity in pad to ensure any spills contained.
- Double isolation valve – preventing storm water from leaving Site
- Storm water to a licensed wastewater treatment works

- Site selection avoided areas at risk of flooding

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Potential for effects associated with :

- the risk to availability of water supplies resulting from demand requirements
- increased run- off leaving the Site and entering field drainage when compared to pre-developed condition.

All would be **negligible or minor beneficial** , except for the risk to availability of water supplies in mains networks during the hydraulic fracturing stage.

Effects

- There would be potential for **one minor adverse** effect at the hydraulic fracturing stage- risk to availability of water supplies in mains network resulting from demand requirements

Further mitigation

- Install PSV and PMV on network to maintain supplies for others and reduce risk of bursts
- More extensive reuse of flow-back water in the fracturing fluid to reduce water demand
- Consider use of collected rainwater in the fracturing fluid to reduce water demand

Residual significance

- Minor adverse effect and **not significant**

The ES concluded that both Projects will **not result in a significant effect** on water resources.

Public Health

Concerns about the long-term effects on health, health impacts of pollution or contamination and the possibility of the hydraulic fracturing process being detrimental to public health.

Public health related issues associated with both Projects have been covered by different sections of the ES.

Our response:

- Public Health England concluded that **"the potential risks to public health in the vicinity of shale gas extraction sites will be low if shale gas extraction is properly run and regulated."**

We intend to:

- Design the well pad to ensure containment of any spillages or potentially polluting materials affecting water courses.
- Design the wells with multiple layers of containment to ensure well integrity.
- Use a flare to burn gas during IFT to reduce concentrations of atmospheric pollutants.
- Ensure any emissions to air do not exceed legal limits

The potentially cumulative effects from both shale gas exploration sites and with other developments within 10km have been assessed.

The ES has concluded that due to the distance between Preston New Road and Roseacre Wood, and the fact that they will be accessed from different roads, **there is limited scope for cumulative effects.**

The project will **not result in a greater number of significant effects** when combined with those from other developments in the vicinity.

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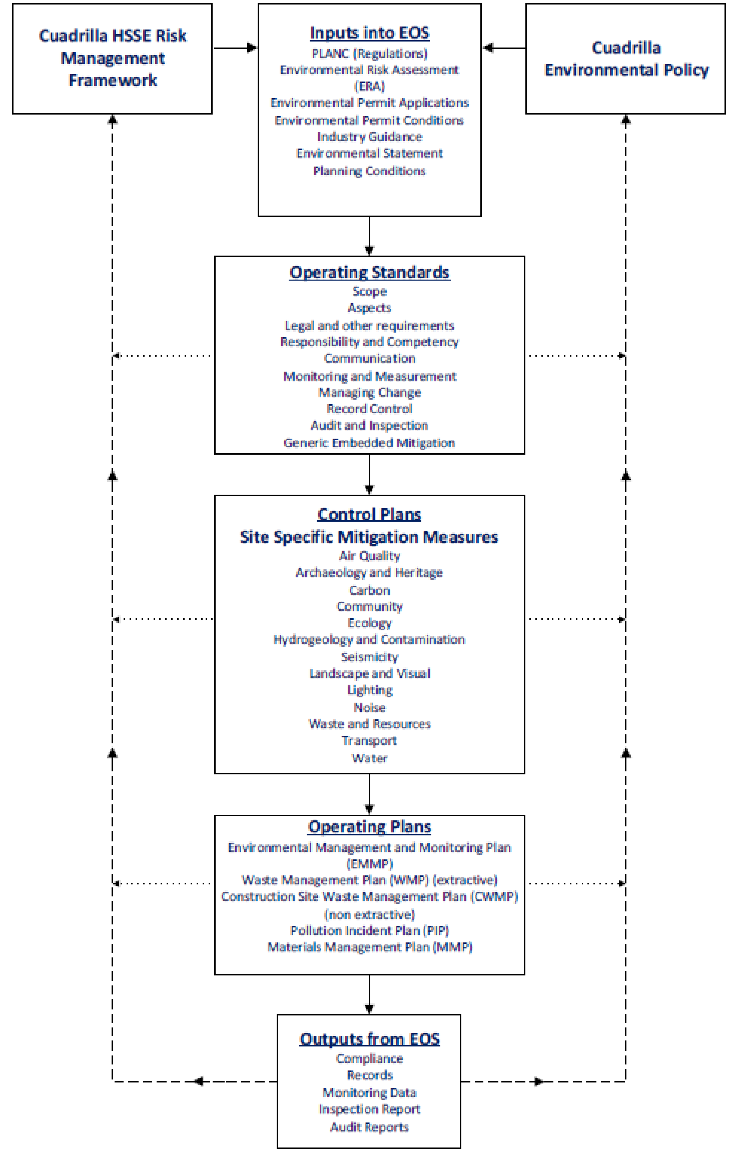
Cuadrilla
Environmental Operating Standards
Structure and Rationale
Version 1

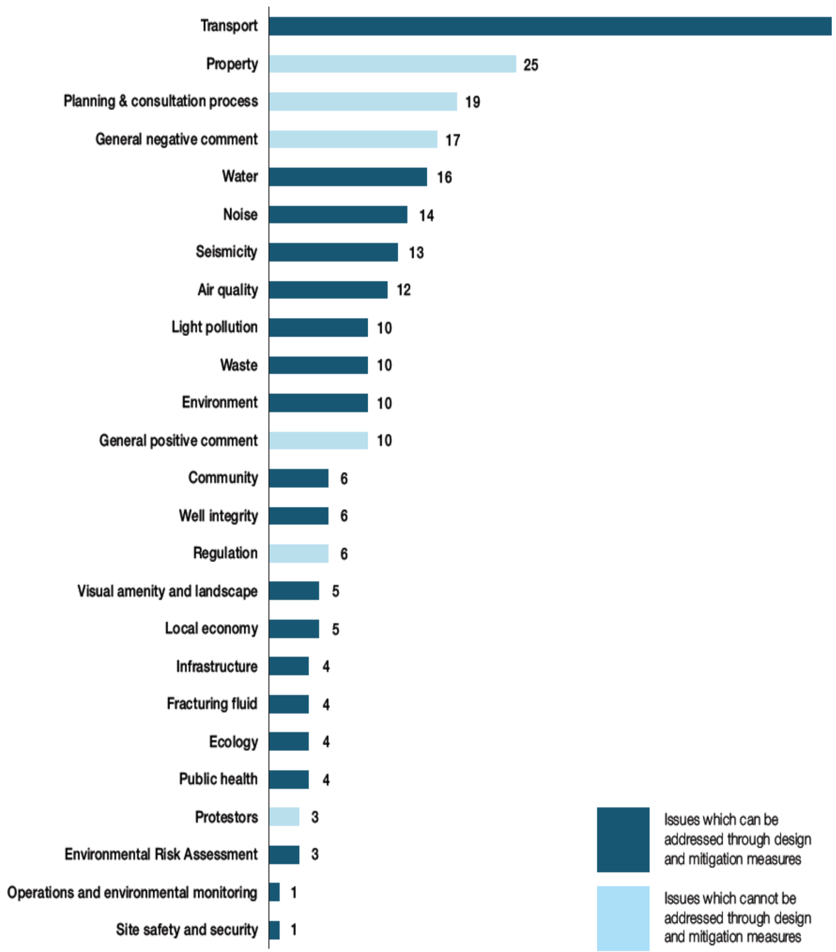

Cuadrilla HSSE Risk Management Framework
Inputs into EOS
PLANC (Regulations)
Environmental Risk Assessment (ERA)
Environmental Permit Applications
Environmental Permit Conditions
Industry Guidance
Environmental Statement
Planning Conditions
Cuadrilla Environmental Policy
Operating Standards
Scope
Aspects
Legal and other requirements
Responsibility and Competency
Communication
Monitoring and Measurement
Managing Change
Record Control
Audit and Inspection
Generic Embedded Mitigation
Control Plans
Site Specific Mitigation Measures
Air Quality
Archaeology and Heritage
Carbon
Community
Ecology
Hydrogeology and Contamination
Seismicity
Landscape and Visual
Lighting
Noise
Waste and Resources
Transport
Water
Operating Plans
Environmental Management and Monitoring Plan (EMMP)
Waste Management Plan (WMP) (extractive)
Construction Site Waste Management Plan (CWMP) (non extractive)
Pollution Incident Plan (PIP)
Materials Management Plan (MMP)
Outputs from EOS
Compliance
Records
Monitoring Data
Inspection Report
Audit Reports

Consultation Process

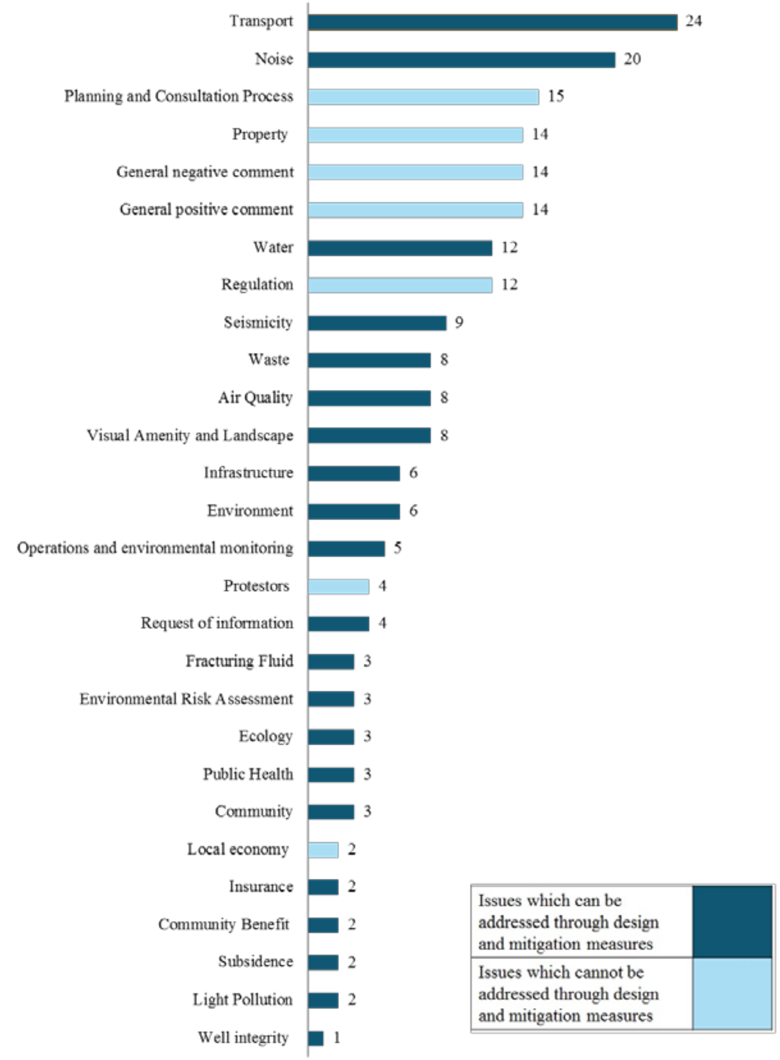
	Project Stage				
	Overview of exploration and introduction to Environmental Risk Assessment	Update on project progress and Environmental Risk Assessment	Announcement of exploration sites and outline of planning and Environmental Impact Assessment process	Emerging findings from the Environmental Impact Assessment for the Exploration site	Post submission of planning application
Consultation Activity	July to October 2013	November to December 2013	January to March 2014	April to May 2014	June 2014 to LCC decision on planning applications
Information day event and exhibition with technical experts available	✓	✓	✓	✓	
Engagement with key bodies	✓	✓	✓	✓	
Workshop events and parish council meetings	✓	✓	✓	✓	
Community Liaison Group meeting				✓	✓
Dedicated phone line	✓	✓	✓	✓	✓
Newsletter distributed		✓	✓	✓	✓
Brochure distributed				✓	✓
Animations and computer generated images available		✓	✓	✓	✓
Community mapping available		✓	✓	✓	
Physical model of site				✓	
Information can be downloaded from website	✓	✓	✓	✓	✓

Principal concerns and ES Assessment Topics

Principal concerns raised Roseacre Wood



Principal concerns raised Preston New Road



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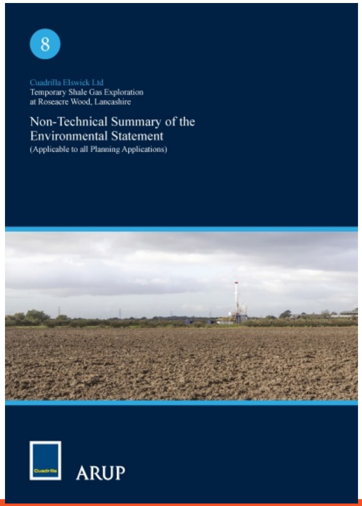
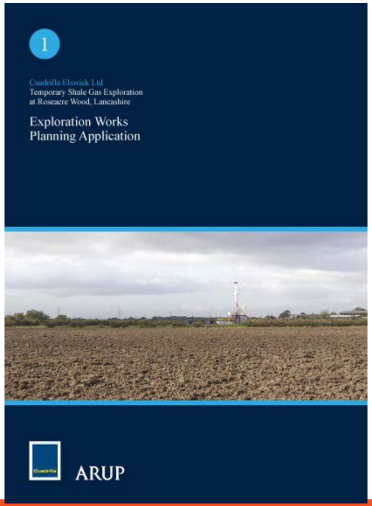
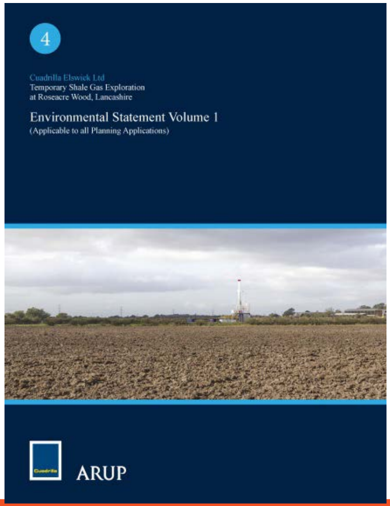
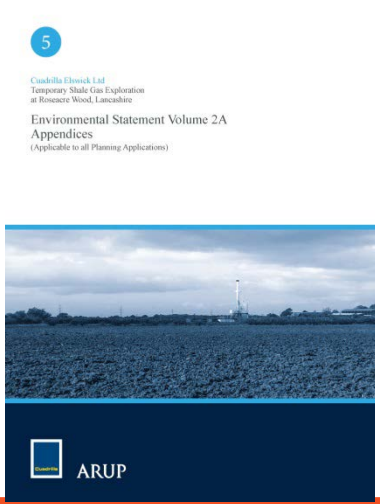
Site / Application	Submission Date	Determination
Preston New Road Exploration Site	29 May 2014	January 2015.
Preston New Road Monitoring Works		January 2015.
Roseacre Wood Exploration Site	16 June 2014	January 2015.
Roseacre Wood Monitoring Works		January 2015.









- Director of Public Health: Health Impact Assessment of sites, followed by HIA of the wider industry.
- Key risks to the health and wellbeing of residents near the two proposed sites:
  - Lack of public trust and confidence, stress and anxiety from uncertainty that could lead to poor mental wellbeing
  - Noise related health effects due to continuous drilling, and
  - Issues related to capacity for flowback waste water treatment and disposal.
- DPH: risks can be mitigated by LCC, EA, DECC, HSE.
  - Vigilant / emergency preparedness.
  - Robust baseline & long term monitoring to reassure communities and understand cumulative and long term effects.
  - Local communities - actively involved & risks communicated in transparent, reliable & proportionate way. Closer working between industry, national, local agencies & others.
  - Local shale gas spatial strategy & national onshore oil and gas integrated regulatory framework. Further research on effects of shale gas development on health and wellbeing.

Permission	Comments	Agency
Environmental Permitting Regulations 2010 (as amended) Schedule 22	Permit required to cover the unlikely possibility of indirect discharge of hydraulic fracturing fluid into a groundwater unit.	Environment Agency
Environmental Permitting Regulations 2010 (as amended) Schedule 20	Permit required for managing extractive wastes which are defined under the Mining Waste Directive.	Environment Agency
Environmental Permitting Regulations 2010 (as amended) Schedule 23	Permit required for the temporary accumulation and disposal of flowback fluid and soil waste containing Naturally Occurring Radioactive Material.	Environment Agency
Environmental Permitting Regulations 2010 (as amended) Schedule 13	Permit required for the incineration (flaring) of hazardous waste (natural gas) greater than 10 tonnes per day.	Environment Agency
The Greenhouse Gas Emissions Trading Scheme Regulations 2012	Permit to emit greenhouse gas as a regulated activity for combustion greater than 20Mwth.	Environment Agency

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Permission	Comments	Agency
Licence to Flare	The main purpose of the licencing process is to ensure that gas is conserved where possible by avoiding unnecessary wastage during the production of hydrocarbons.	DECC
Consents for Operations	All operations including drilling, hydraulic fracturing, well suspension, well re-entering etc. require DECC approval via the WONS (well operations and notifications system). Hydraulic Fracturing Programme to be submitted to DECC after the well is drilled and prior to fracturing operations.	DECC
Notification of Operations	All operations including drilling, hydraulic fracturing, well suspension, well re-entering etc need to be notified 21 days in advance of the operation.	HSE
Notification of Operations	Drilling operations need to be notified in advance of the operation.	British Geological Society

Questions & Comments

Shale Gas Case Study!

Des Correia, Director, Arup
November 2014

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