Is groundwater at risk from shale gas exploration?

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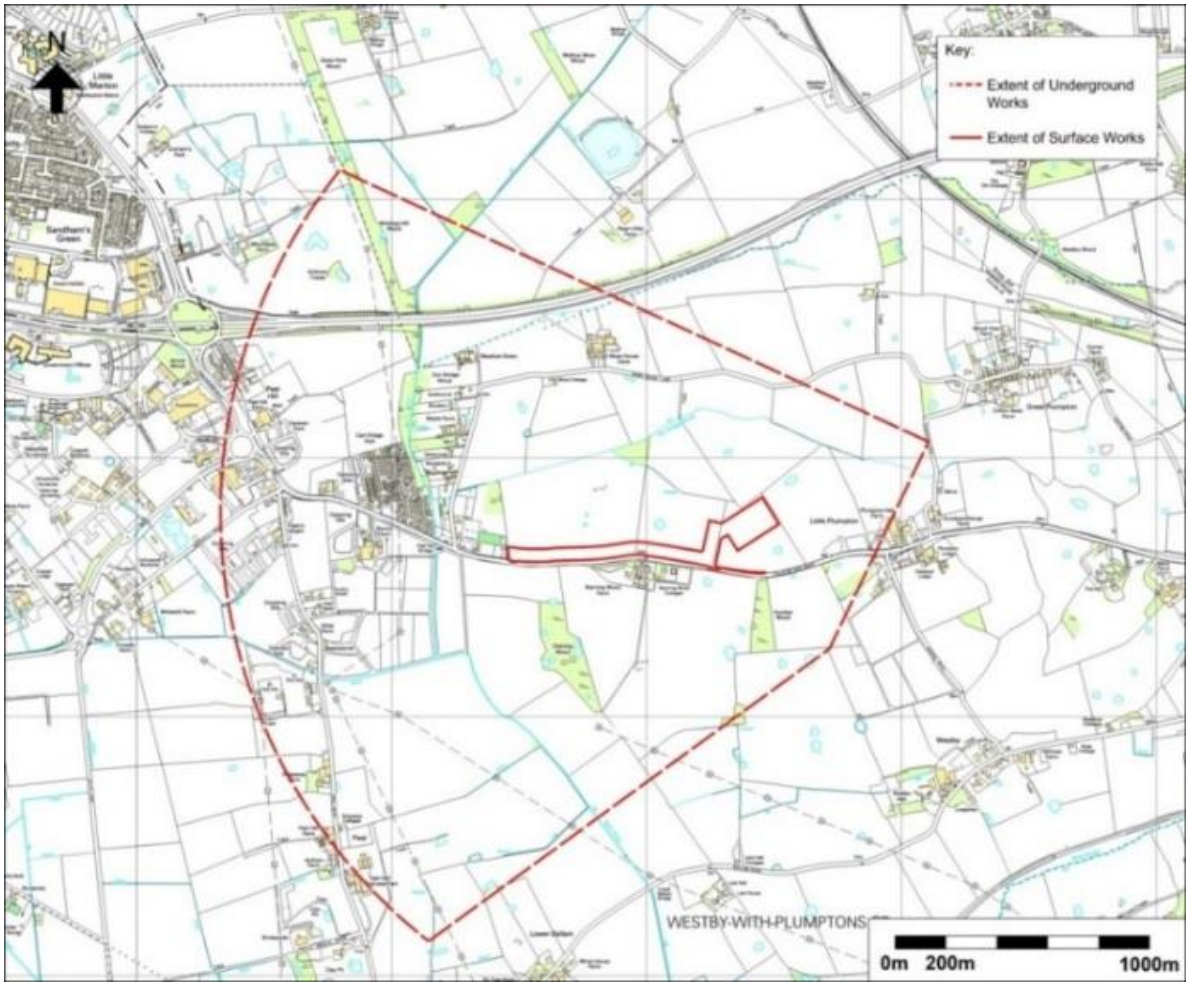
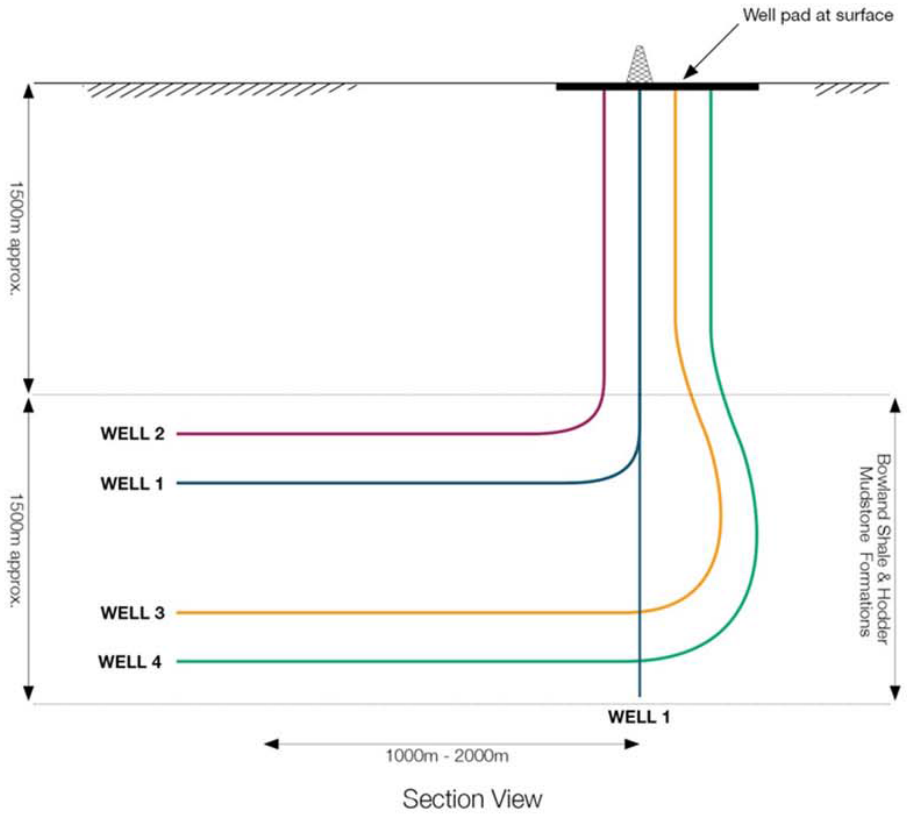
Cuadrilla proposals in Lancashire

Planning applications for temporary exploration of shale gas at two sites, Preston New Road and Roseacre Wood



Cuadrilla proposals



- Construction
- Drilling
- Hydraulic fracturing
- Well testing
  - Suspend and apply for production
  - Decommission wells

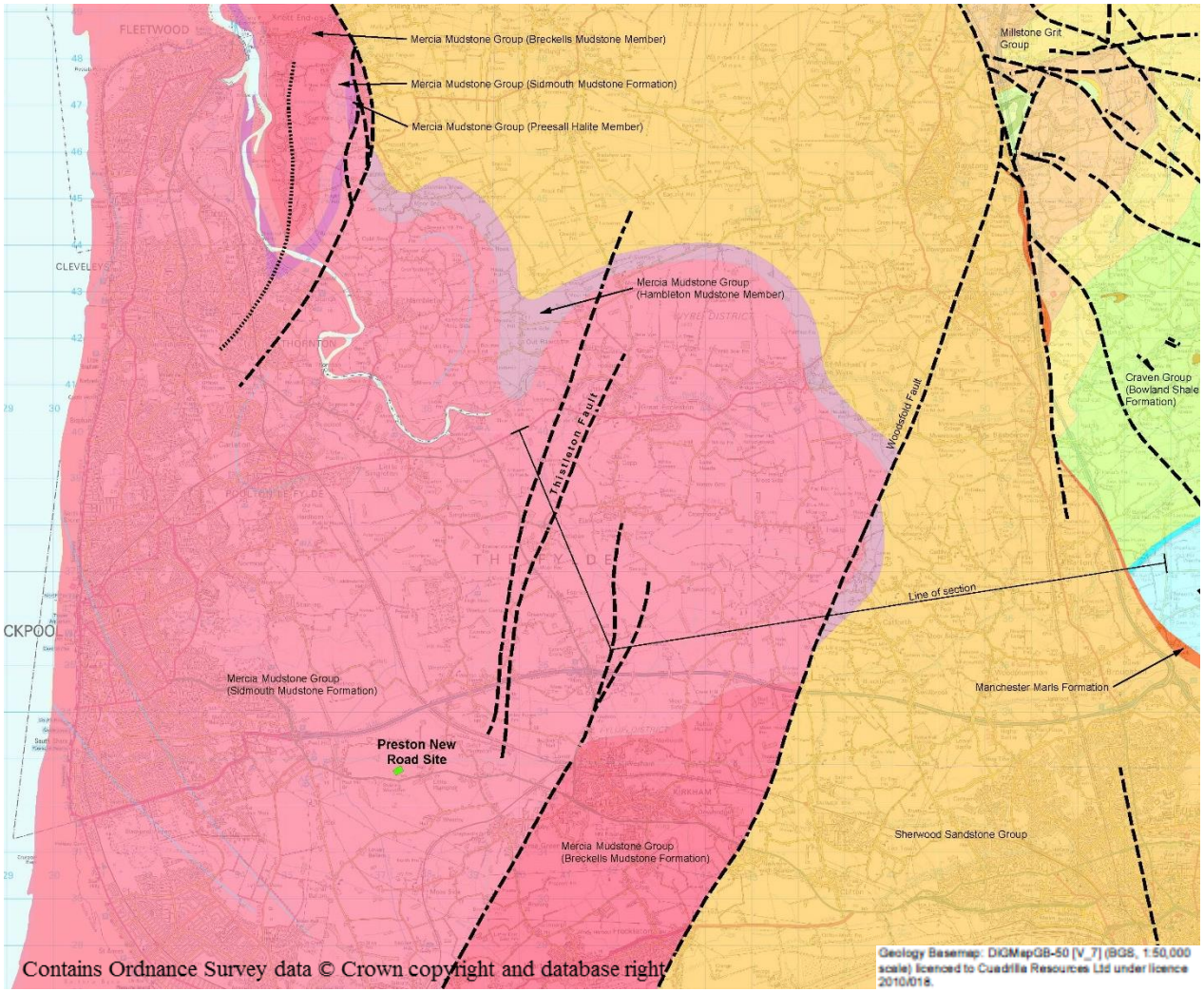
Understanding the risks to groundwater

- Baseline conditions

1. Surface activities
2. Drilling and well integrity
3. Hydraulic fracturing and fracture propagation

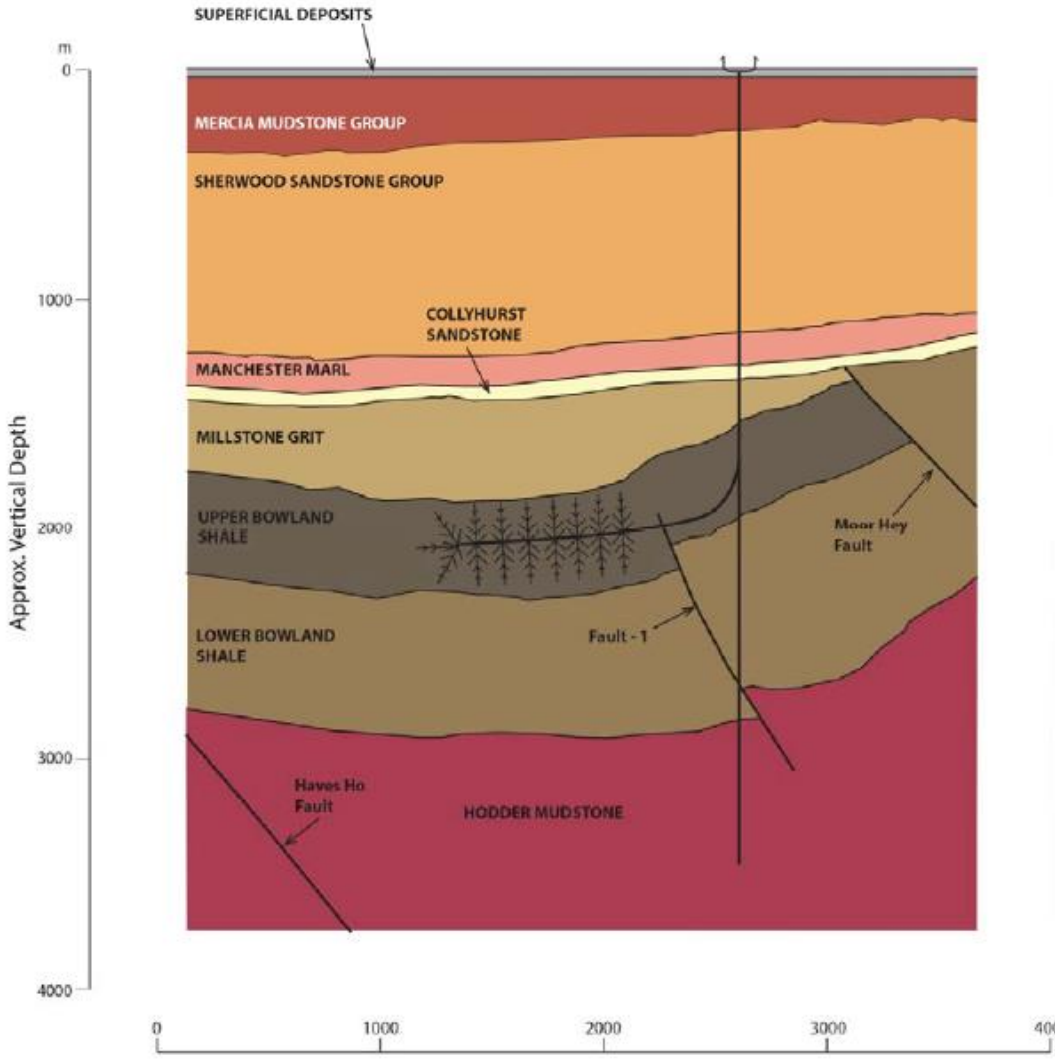
Bedrock geology

- NNE-SSW trending extensional faults
- Woodsfold Fault
- Groundwater units

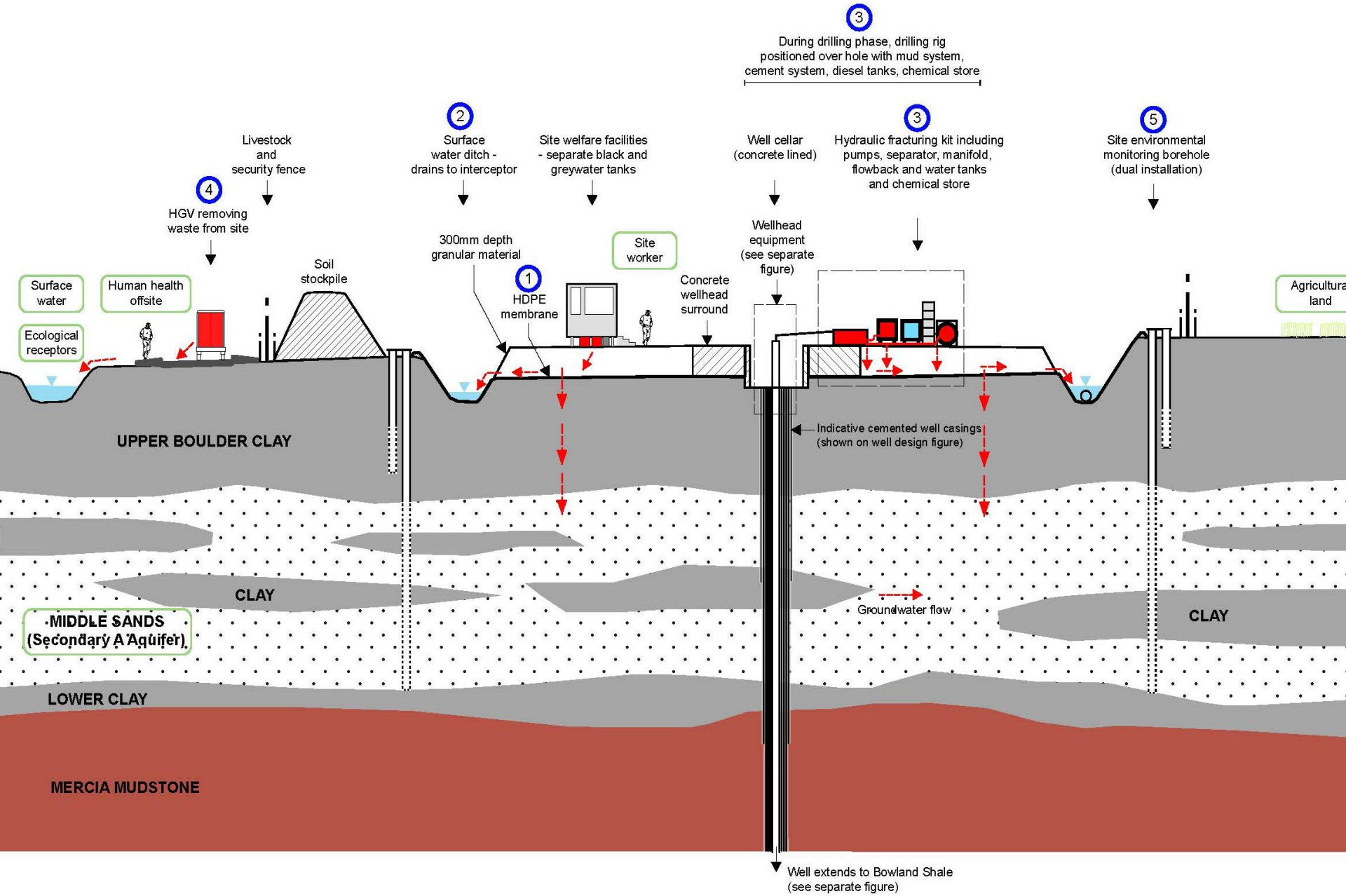


Groundwater baseline

- Middle Sands
- Sherwood Sandstone (>250m depth and poor quality)
- Manchester Marl
- No regional faults
- Woodsfold Fault 8km east



Groundwater risk assessment:
1. Surface activities


3
During drilling phase, drilling rig positioned over hole with mud system, cement system, diesel tanks, chemical store
2
Surface water ditch - drains to interceptor
Site welfare facilities - separate black and greywater tanks
Well cellar (concrete lined)
3
Hydraulic fracturing kit including pumps, separator, manifold, flowback and water tanks and chemical store
5
Site environmental monitoring borehole (dual installation)
Livestock and security fence
4
HGV removing waste from site
300mm depth granular material
1
HDPE membrane
Site worker
Wellhead equipment (see separate figure)
Concrete wellhead surround
Soil stockpile
Surface water
Human health offsite
Ecological receptors
Agricultura land
UPPER BOULDER CLAY
Indicative cemented well casings (shown on well design figure)
CLAY
Groundwater flow
MIDDLE SANDS (Secondary A Aquifer)
CLAY
LOWER CLAY
MERCIA MUDSTONE
Well extends to Bowland Shale (see separate figure)

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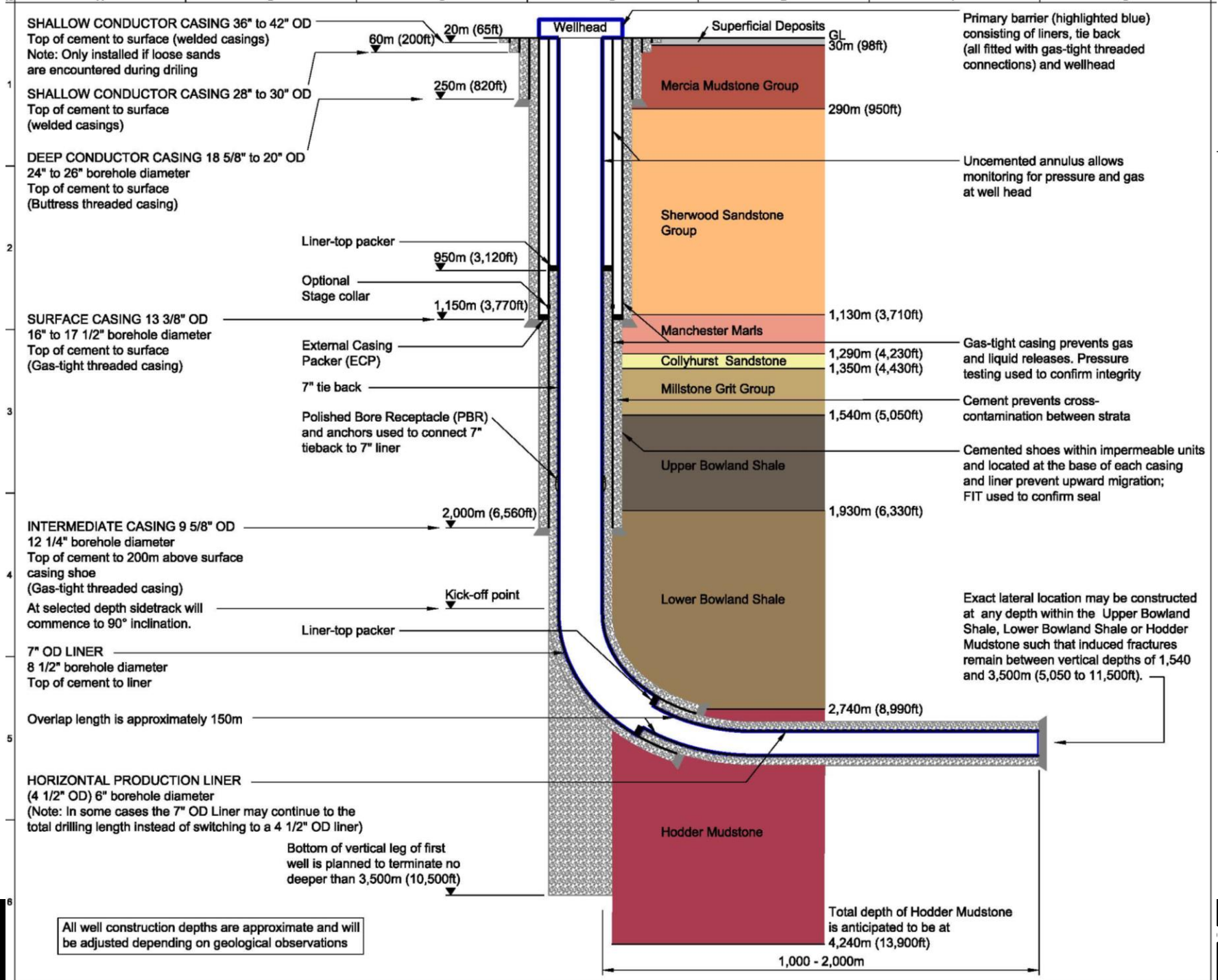
Groundwater risk assessment:
2. Drilling and well integrity


SHALLOW CONDUCTOR CASING 36" to 42" OD
Top of cement to surface (welded casings)
Note: Only installed if loose sands are encountered during driling
20m (65ft)
60m (200ft)
SHALLOW CONDUCTOR CASING 28" to 30" OD
Top of cement to surface (welded casings)
250m (820ft)
DEEP CONDUCTOR CASING 18 5/8" to 20" OD
24" to 26" borehole diameter
Top of cement to surface
(Buttress threaded casing)
Wellhead
Superficial Deposits
GL
30m (98ft)
Mercia Mudstone Group
290m (950ft)
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
Sherwood Sandstone Group
Liner-top packer
950m (3,120ft)
Optional
Stage collar
1,150m (3,770ft)
SURFACE CASING 13 3/8" OD
16" to 17 1/2" borehole diameter
Top of cement to surface
(Gas-tight threaded casing)
External Casing Packer (ECP)
1,130m (3,710ft)
Manchester Marls
Gas-tight casing prevents gas and liquid releases. Pressure testing used to confirm integrity
1,290m (4,230ft)
Collyhurst Sandstone
1,350m (4,430ft)
7" tie back
Millstone Grit Group
Cement prevents cross-contamination between strata
1,540m (5,050ft)
Polished Bore Receptacle (PBR) and anchors used to connect 7" tieback to 7" liner
Upper Bowland Shale
Cemented shoes within impermeable units and located at the base of each casing and liner prevent upward migration; FIT used to confirm seal
2,000m (6,560ft)
1,930m (6,330ft)
INTERMEDIATE CASING 9 5/8" OD
12 1/4" borehole diameter
Top of cement to 200m above surface casing shoe
(Gas-tight threaded casing)
Lower Bowland Shale
Kick-off point
At selected depth sidetrack will commence to 90° inclination.
Liner-top packer
Exact lateral location may be constructed at any depth within the Upper Bowland Shale, Lower Bowland Shale or Hodder Mudstone such that induced fractures remain between vertical depths of 1,540 and 3,500m (5,050 to 11,500ft).
7" OD LINER
8 1/2" borehole diameter
Top of cement to liner
2,740m (8,990ft)
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)
Hodder Mudstone
Bottom of vertical leg of first well is planned to terminate no deeper than 3,500m (10,500ft)
Total depth of Hodder Mudstone is anticipated to be at 4,240m (13,900ft)
1,000 - 2,000m
All well construction depths are approximate and will be adjusted depending on geological observations

Groundwater risk assessment:
2. Drilling and well integrity

Groundwater protection measures

- Wells drilled, constructed and integrity tested in accordance with regulatory requirements and industry best practice
- No hazardous substances in drilling fluids above the Manchester Marl
- Drilling fluid additives identified in the environmental permit
- Well barriers and verification (Independent Well Examiner)
- Approved abandonment design

Multiple failures must occur for environmental release

Barrier failure vs well integrity failure

Groundwater risk assessment:
3. Hydraulic fracturing and fracture propagation

Fracturing fluid composition

- Water
- Sand proppant
- Polyacrylamide (0.05% vol)

No GWD hazardous substances used

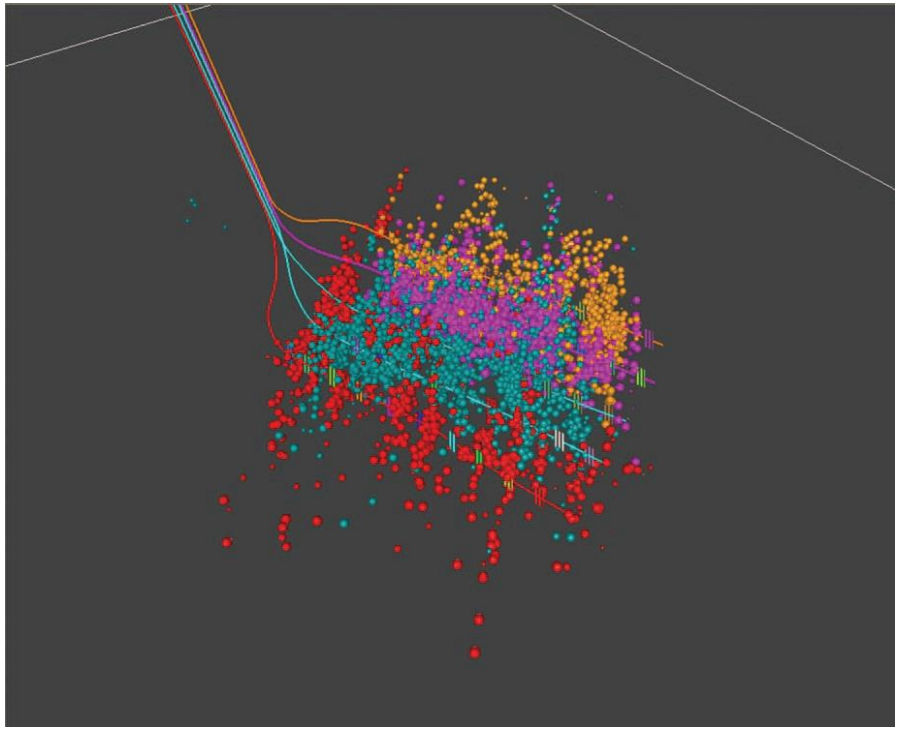
Full disclosure

Flowback composition

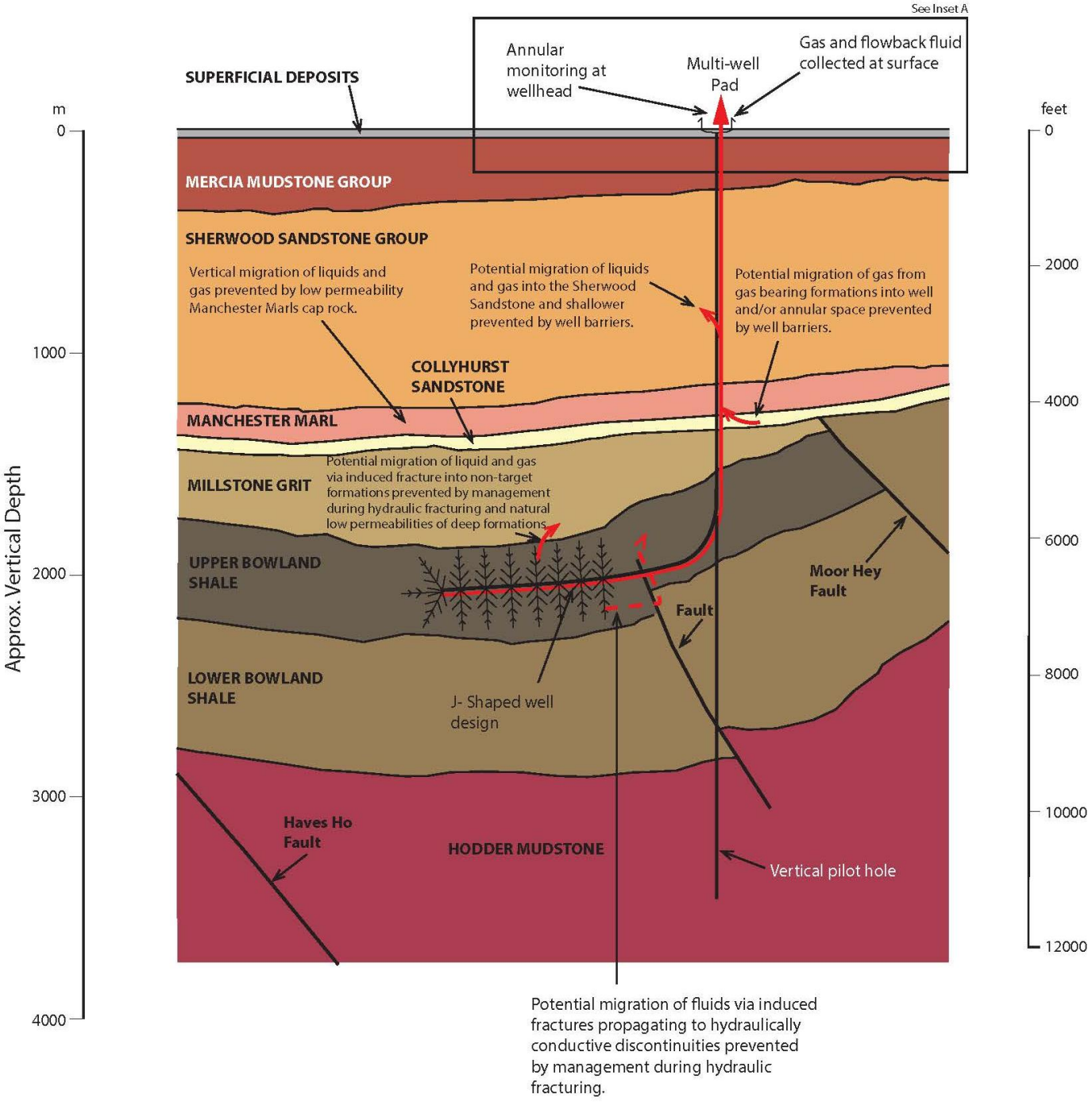
Groundwater risk assessment:
3. Hydraulic fracturing and fracture propagation

How do we know the fractures will stay in the target zone?

- Predictive modelling
- International studies of fracture growth
- Hydraulic Fracture Programme
- Mini fracture prior to main hydraulic fracture
- Reduced volumes injected compared to Preese Hall and flow back between stages
- Microseismic monitoring (80+ locations)



Microseismic monitoring of fracture evolution (Duncan and Eisner 2010).


See Inset A
Annular monitoring at wellhead
Multi-well Pad
Gas and flowback fluid collected at surface
SUPERFICIAL DEPOSITS
m
0
1000
2000
3000
4000
Approx. Vertical Depth
feet
0
2000
4000
6000
8000
10000
12000
MERCIA MUDSTONE GROUP
SHERWOOD SANDSTONE GROUP
Vertical migration of liquids and gas prevented by low permeability Manchester Marls cap rock.
Potential migration of liquids and gas into the Sherwood Sandstone and shallower prevented by well barriers.
Potential migration of gas from gas bearing formations into well and/or annular space prevented by well barriers.
COLLYHURST SANDSTONE
MANCHESTER MARL
MILLSTONE GRIT
Potential migration of liquid and gas via induced fracture into non-target formations prevented by management during hydraulic fracturing and natural low permeabilities of deep formations
UPPER BOWLAND SHALE
Moor Hey Fault
Fault
LOWER BOWLAND SHALE
J- Shaped well design
Haves Ho Fault
HODDER MUDSTONE
Vertical pilot hole
Potential migration of fluids via induced fractures propagating to hydraulically conductive discontinuities prevented by management during hydraulic fracturing.

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Conclusions

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Conclusions: Is groundwater at risk from shale gas exploration?

- Groundwater and ground gas risks are highly site specific
- Well design and site implementation (drilling and site management practices) are important
- Groundwater risks associated with shale gas exploration proposed in Lancashire are manageable
- Regulator approval secured for groundwater aspects for Cuadrilla EIA
- Monitoring and data collection essential to build evidence base and public confidence
- Assessments are in the public domain http://www.cuadrillaresources.com/our-sites/locations/preston-new-road/

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