Working Hypothesis - Executive Summary

This document sets out a working hypothesis concerning the origin and significance of recurring hydrogeological, geomorphological, geochemical and surface-expression changes observed around Preston New Road, Peel Hill, Wakepark and the wider Fylde landscape since 2011.

The hypothesis is that operations at Preese Hall and Preston New Road perturbed a pre-existing faulted and hydrogeologically sensitive system. That perturbation may have altered subsurface pressure, shallow groundwater routing, geochemical conditions and ground stability across a connected landscape. The resulting response may include seepage, prolonged saturation, mobilisation and removal of fines, soil piping or suffosion, local collapse, progressive surface lowering, changing redox conditions and reorganisation of drainage and discharge points.

The present evidence does not establish a single source or mechanism. In particular, it does not yet distinguish between:

- disturbance or damage within the shallow aquifer and superficial deposits;
- pressure transmission along one or more faults without deep fluids reaching the surface;
- fault-mediated upward or lateral migration of deeper groundwater or formation fluids;
- gas-phase migration or pressure-driven redox and biogeochemical alteration within shallow groundwater;
- leakage associated with the well, annuli, pad, cellar, drainage or containment system;
- seismic shaking, fault slip or stress redistribution affecting saturated superficial deposits, shallow permeability, drainage systems or engineered interfaces;
- or a coupled mechanism involving more than one of these processes.

Pressure transmission and shallow-system reorganisation are therefore the minimum hypothesis. Deep-fluid migration, gas migration and well-related leakage remain plausible but unproven extensions requiring direct testing. The landscape response may also be sequential: stress change or compaction may alter permeability and drainage, after which groundwater movement, fines loss and collapse develop progressively.

The proposed causal setting is anthropogenic disturbance of an already sensitive natural system, rather than replacement of natural processes by wholly artificial ones. Natural iron precipitation, saline or mineralised groundwater, organic films, shrink-swell, consolidation, agricultural drainage and ordinary erosion may all contribute to individual manifestations. The central question is whether those processes were activated, accelerated, redirected or made more extensive by operations at Preese Hall and Preston New Road.

The competing explanations are not limited to hydrocarbon operations and natural background. Agricultural drainage and soil treatment, lime or fertiliser, road salt and highway runoff, leaking water or sewer infrastructure, historic land use or waste disposal, construction materials, peat removal, old boreholes and other unrelated human activities must also be mapped and tested. Their ability to explain an individual feature would not automatically explain the spatial-temporal pattern as a whole.

The timing is an important part of the hypothesis. The archive records an apparent increase in unusual water, ground and vegetation expressions after the 2011 Preese Hall induced-seismicity event, followed by a marked expansion during and after PNR construction and operations from

2017 onwards. Relevant PNR events include major earthworks and loading, modification of drainage, construction of a large impermeable platform, the unexpected encounter with an artesian horizon, repeated pad-water behaviour, hydraulic fracturing and induced fault activation. Temporal association does not itself prove causation, but it provides a rational basis for investigating whether the operations acted as triggers or amplifiers.

LiDAR differencing and repeat imagery demonstrate spatially organised elevation change, depressions, scarps and altered drainage geometry across parts of the study area. These data can identify where ground has lowered and where forms have developed that are consistent with seepage erosion, fines migration or collapse. LiDAR alone cannot diagnose those mechanisms. The historical image and video archive provides the temporal and surface-process context by recording water emergence, staining, mounds, vegetation change, pond evolution and collapse at or near the mapped areas of change.

At the well pad, repeated resurfacing and aggregate addition did not permanently remove the spatial pattern of depressions, wetting and fluid accumulation; comparable expressions returned at fixed or closely similar locations, indicating a persistent control beneath or within the repeatedly modified surface layer.

The working interpretation is therefore of a connected but heterogeneous system. A common change in hydraulic pressure, gas movement or flow regime would not necessarily produce identical surface expressions everywhere. Depending on local geology, sediment structure, drainage, topography, land use, redox state and chemistry, the same wider disturbance could produce mineral precipitation at one location, bubbling or gas release at another, seepage and bank erosion elsewhere, and ground lowering or pond formation where the superficial deposits are most vulnerable. The material visible at the surface need not itself originate at depth: pressure or gas movement could alter shallow groundwater chemistry and mobilise or precipitate material already present in the near-surface environment.

Classes of manifestation observed to date

Water and discharge behaviour

Reported observations include new or recurring seepage, wet ground in elevated or drought-affected settings, bank-face discharge, persistent ponding, altered field drainage, water emerging at fixed pad and landscape locations, and changes in the position or intensity of discharge points.

Ponds and water bodies have shown apparent changes in shape, extent, colour and persistence. Bubbling has been recorded at fixed points in some ponds. Water has variously appeared brown, red, green, olive or unusually dark, sometimes with sediment, surface films or iridescence.

Gas-phase and biogeochemical behaviour

Reported observations include fixed bubbling points, changing pond colours, unusual odour reports in parts of the wider historic record, iridescent or biological-looking films and repeated sediment precipitation. These observations do not establish thermogenic gas, contamination or a common source.

They raise the possibility that gas movement, oxygen depletion, redox alteration or microbial processes may contribute to the observed water and sediment behaviour. Methane or another

reduced gas could alter shallow groundwater chemistry without the visible surface material itself originating from the shale. This remains a mechanism to test, not a conclusion.

Ground deformation and lowering

Observed forms include measurable lowering, circular and irregular depressions, scarps, cracks, elongated surface breaks, undulations, local collapses, bank failure and altered road or field geometry.

LiDAR comparison between available epochs identifies spatially organised negative elevation change in parts of the corridor. The mechanism of that lowering is not established and may include consolidation, shrink-swell, drainage change, shaking-induced rearrangement, permeability alteration, fines migration, repeated saturation, local collapse or land-management effects.

Seepage-erosion and soil-piping-type morphology

Some features resemble forms produced by seepage erosion or internal removal of fine material, including headward scarps, amphitheatre-like depressions, branching forms, holes, channels, mounds with associated depressions and progressive collapse.

Experimental seepage-erosion literature provides a valid morphological and physical comparator, but similarity of shape does not establish that the same process occurred in the field. Ground verification and hydrogeological measurement are required.

Mounds, vents and surface openings

Repeated mound-like, vent-like or molehill-like expressions have been documented in fields, verges and water-adjacent ground. Some later collapse, become surrounded by wet ground, occur near depressions or appear in aligned or branching arrangements.

Individual features may have ordinary animal or agricultural explanations. Their potential significance lies in recurrence, spatial organisation, temporal development and association with water, gas-like bubbling or later lowering.

Sediment, staining and surface films

Red, orange, purple and dark sediment or staining has been recorded in fields, ponds, drains, watercourses and at pad margins. Iridescent or reflective surface films have also appeared at multiple locations.

Natural iron ochre, organic material, biological films, agricultural inputs and hydrocarbons can produce overlapping appearances. Colour and sheen are therefore treated as observational categories rather than chemical identification. Their value lies in repeat location, timing, recurrence and association with other manifestations.

Pale or white residues and salt-like expressions

Recent observations include pale, white or grey surface material, apparent crusting or precipitation, bare-centred patches and widespread vegetation loss or stress, sometimes in or near low, wet or previously stained areas.

These features may be consistent with salt accumulation, evaporative concentration or other mineral precipitation. They may also result from lime, fertiliser, carbonate, sulfate, construction material, drought or ordinary soil processes. Salinity is not established without electrical-conductivity, ion-chemistry and mineralogical testing.

Vegetation and ecological response

Reported vegetation expressions include red or purple discolouration, low growth, bare patches, abrupt vegetation boundaries, loss of crop or pasture, dead plants and repeated poor regrowth. Dead fish and animal carcasses have also been reported in some parts of the wider record.

These observations are non-specific. Their evidential value lies in their location, timing, recurrence and relationship to water, staining and ground forms, not in any single appearance. Ecological assessment would need to consider aquatic invertebrates, soil organisms, microbial communities, habitat condition, oxygen depletion and the possible combined effects of chemical and physical stressors.

Pad surface, aggregate and containment-interface behaviour

The Preston New Road pad exhibits three related but evidentially distinct classes of recurring behaviour.

First, aerial imagery documents depressions, darkened surface zones, aggregate redistribution and fluid-filled lows recurring at spatially similar locations over multiple years. These features persisted or returned after episodes of surface reworking, regrading and the addition of gravel or aggregate. Their recurrence after intervention is consistent with a fixed underlying hydraulic, structural or loading control rather than a single superficial irregularity. It does not establish subgrade collapse, voiding or membrane failure; persistent drainage geometry, equipment loading and ordinary aggregate consolidation remain relevant alternatives.

Second, drilling-related and other operational fluids have been visibly present on the engineered pad surface during several phases of its use. Repeated staining, wetting and sediment accumulation are documented at the well-cellar interface and in fixed perimeter zones. Additional aggregate was subsequently placed over or adjacent to some areas that had previously exhibited fluid accumulation or discolouration. The present record does not establish the chemistry or source of every fluid expression, but it supports the need to determine whether aggregate, fines and underlying materials were affected and how they should be characterised before removal.

Third, exposed sections of the membrane and perimeter interface show recurring tonal darkening, local deterioration, wrinkling, irregular fence-to-ground contact and spatial correspondence between internal and external fluid accumulation. At some locations, trenches, gravel drains, barriers, access structures and hoses were introduced following earlier water-related expressions. These observations do not demonstrate a membrane breach. They do show that the integrity and hydraulic behaviour of the containment boundary cannot be resolved solely through the absence of an obvious visible tear.

The quantity, distribution and timing of additional aggregate placed on the pad have not yet been established. Those records are material because repeated aggregate addition may have altered loading and drainage while also obscuring earlier surface conditions. The recurrence of comparable

depressions and wet zones after resurfacing provides a testable reason to examine the subgrade, membrane interfaces and underlying materials before irreversible removal.

Gamma-radiation variation

Exploratory surveys have identified localised near-ground increases in gamma count rate and dose relative to nearby controls, with values decreasing toward background at greater detector height in at least one tested location.

No radionuclide source has been identified. The current evidence supports spatial variation in near-ground gamma response, not a conclusion of NORM mobilisation, contamination, exposure risk or food-chain transfer.

Potential receptors and exposure pathways

Agricultural, ecological and food-chain receptors

The study area is an agricultural landscape containing grazed pasture, cultivated fields, ponds, field drains and connected watercourses. If the proposed disturbance has altered the movement or chemistry of shallow groundwater, potential exposure pathways include root-zone contact and plant uptake, deposition of dissolved or suspended material during flooding, livestock ingestion of affected water, pasture or soil, consumption of affected fodder, and transfer through aquatic organisms.

The current observations do not establish contamination, toxic exposure, biological uptake or a food-safety consequence. They identify plausible receptors and justify testing whether affected soils, waters, plants or animals differ materially from suitable local controls. Assessment should proceed sequentially: identify the environmental material, establish mobility and exposure, and only then undertake plant, animal or food-product testing where the environmental results justify it.

Food-chain reassurance may depend on an upstream environmental or animal-health body first recognising and communicating a qualifying pollution or farm incident. The absence of such an upstream classification is not equivalent to evidence that the environmental pathway was tested. This is a governance question, not proof of food contamination.

Human contact, air and public-access receptors

Potential but unproven exposure routes include direct contact with standing water, sediment or residues; inhalation of gas, vapour or dust near active emergence points or during deconstruction; and gas accumulation where a pathway reaches an enclosed space. No human exposure or health effect is established by the current evidence. The purpose of identifying these routes is to ensure that sampling and risk assessment are receptor-aware.

Drinking-water and abstraction receptors

The Fylde groundwater and surface-water systems are interconnected and support licensed, industrial and potentially private abstractions. The present project has not yet mapped all boreholes, springs, wells or downgradient abstractions sufficiently to determine whether any used water source lies on a plausible pathway. Receptor mapping and review of historic and contemporary chemistry are therefore required before drinking-water relevance can be excluded.

Built environment and public infrastructure

Observed ground and water manifestations occur beside roads, verges, paths, drains, junctions, utilities, pylons, field access points and residential boundaries. Potential consequences include settlement, changing road camber, culvert or pipe deformation, drainage failure, loss of field access, utility-foundation movement or property-related ground adjustment. The current evidence does not attribute damage to PNR or Preese Hall; it identifies infrastructure as a receptor class that should be mapped against the observed hydraulic and lowering corridors.

Temporal behaviour, lag and stress amplifiers

The hypothesis includes delayed, episodic and hysteretic behaviour. Some manifestations may respond immediately to rainfall, recharge, pressure change, ground disturbance or seismicity; others may appear after a lag as pressure diffuses, groundwater rises, sediments weaken, fines are removed or dissolved material precipitates during drying.

Heavy rainfall, prolonged drought followed by recharge, seasonal groundwater rise, barometric change, tidal influence in low-lying connected systems, drain clearance or obstruction, seismic events and pad loading or removal may each modify the visibility or intensity of a manifestation. Weather and climate variability are treated as stress amplifiers and observation controls, not as proof of the initiating cause.

Absence of a manifestation during a later inspection does not establish absence during the active event. Continuous measurements, event-triggered sampling and analysis of deposited soil or sediment are therefore required to resolve transient pathways and retained evidence.

Deconstruction, waste and remobilisation

Deconstruction is both an evidential opportunity and a new system perturbation. Removal of aggregate, drainage structures and membrane may expose previously concealed conditions, but may also alter loading, subgrade stress and hydraulic gradients, redistribute fines or fluids, and remove the present engineered configuration before it is characterised.

A proportionate process should therefore record aggregate delivery and removal quantities, map excavation stages, preserve a pre-removal surface model, sample materials by location and depth, inspect the membrane and subgrade, document unexpected water, gas, odour, staining, voiding or deformation, and apply clear hold points before evidence is covered, mixed or removed. Waste classification and chain of custody are part of the environmental test, not merely disposal administration.

Post-deconstruction monitoring may also be required if seepage, pressure change, gamma variation or ground adjustment persists after the site configuration has been altered.

Evidential position

The available evidence supports the hypothesis as a coherent, scientifically plausible explanation requiring targeted investigation. It does not yet prove:

- that the manifestations have a common cause;
- that deep or formation fluids, or thermogenic gas, have reached the surface;

- that PNR or Preese Hall caused any particular feature;
- that the well, pad or containment system leaked;
- that salinity, hydrocarbons, harmful metals or NORM are present;
- that crops, livestock, wildlife, drinking-water sources, people or infrastructure have been materially exposed or harmed;
- or that fault-mediated transport occurred.

The strongest current evidence concerns pattern, timing, recurrence, spatial organisation, repeat location and measurable ground change. The weakest evidence concerns chemical source, gas identity, hydraulic connectivity, biological uptake and causal attribution.

Principal question

The central unresolved question is:

> What is driving the repeated pressure, fluid emergence, geochemical expression and ground adjustment across this landscape; is that driver associated with shallow-aquifer disturbance, fault-mediated pressure or fluid migration, gas movement, seismic or stress-induced ground change, the well or pad system, another anthropogenic source, or a coupled interaction among them; and have the resulting soil, water, sediment or air conditions created any material pathway to crops, livestock, wildlife, water supplies, people or infrastructure?

Discriminating hypotheses and expected evidence

The required investigation should be designed to distinguish explicit competing explanations rather than simply establish that a location is unusual.

Shallow aquifer or drainage reorganisation

Expected indications would include strong rainfall or seasonal response, shallow hydraulic gradients connecting the features, and chemistry consistent with local shallow groundwater. The explanation would be weakened by absence of spatial hydraulic connection or by manifestations that remain independent of groundwater and drainage behaviour.

Fault-mediated pressure transmission

Expected indications would include correlated pressure or water-level responses along a structural corridor, possibly without a distinctive deep-fluid chemistry. The explanation would be weakened if no pressure coherence is found and the pattern is fully explained by local topography, drainage and land management.

Deep fluid or gas migration

Expected indications would include saline or formation-like ion ratios, diagnostic dissolved gases, isotopic evidence, or barium, strontium, bromide or radionuclide patterns inconsistent with shallow controls. The explanation would be weakened if chemistry and gases are indistinguishable from suitable shallow-groundwater and soil controls.

Well, annulus, pad or containment pathway

Expected indications would include a spatial or chemical gradient from the pad, correspondence with operational fluids, integrity or drainage anomalies, or repeat behaviour at engineered interfaces. The explanation would be weakened if material signatures do not match, hydraulic direction is incompatible, and integrity and fluid-balance records exclude the proposed route.

Seismic or stress-induced ground response

Expected indications would include temporal or spatial correspondence with induced seismic sequences, compaction, cracking, permeability change or drainage disruption within susceptible saturated deposits. The explanation would be weakened if comparable change clearly predates the seismic events or no relationship exists after controlling for land use and hydrology.

Natural processes

Expected indications would include comparable manifestations in the historical baseline and in matched unaffected landscapes with similar geology, drainage and management. A purely natural explanation would be weakened by a clear post-operational emergence or acceleration absent from appropriate controls.

Other anthropogenic sources

Expected indications would include chemistry, geometry or timing matching agricultural treatment, road runoff, sewer or water leakage, construction material, waste, old wells or another local activity. Such an explanation would be weakened where the pattern crosses those sources, precedes them, or has an incompatible chemical or spatial fingerprint.

Evidence required to resolve the hypothesis

Hydrogeology and timing

- targeted shallow piezometers across and outside the suspected corridors, with continuous groundwater-level and pressure logging;
- hydraulic-gradient mapping, review of historic borehole data and mapping of springs, drains, licensed and private abstractions;
- synchronised rainfall, drain level, pond level, conductivity, temperature and surface-movement records;
- event-triggered sampling during active seepage, bubbling, flooding, staining or rainfall response, not only scheduled visits; and
- assessment of tidal, barometric, seasonal and deconstruction-related influences where relevant.

Chemistry, gas and redox

- manifestation-specific soil, sediment and water sampling with matched local controls;
- electrical conductivity, pH, dissolved oxygen, oxidation-reduction potential, alkalinity and total dissolved and suspended solids;

- major ions including chloride, sodium, calcium, magnesium, sulfate, bicarbonate and potassium;
- iron and manganese in dissolved and particulate fractions, plus barium, strontium, bromide, boron, lithium and other source-discrimination parameters where justified;
- dissolved methane, ethane and propane, headspace sampling at active bubbles, and carbon or hydrogen isotope analysis where gas is detected;
- hydrocarbon screening, sulfide and relevant microbiological examination where films, odour or unusual growth are present; and
- controlled gamma surveys followed by laboratory gamma spectrometry and radionuclide-specific analysis where screening justifies it.

Ground mechanics and topography

- repeat high-resolution LiDAR, RTK survey, photogrammetry or precision levelling using stable control;
- geotechnical assessment of active scarps, voids, depressions, banks and collapse heads;
- grain-size, density, moisture, permeability and fines-migration assessment of affected and control materials;
- shallow geophysics where suitable to identify voiding, disturbed horizons or preferential pathways; and
- correlation of ground change with rainfall, seismicity, drainage works, loading and known land-management interventions.

Pad, well and deconstruction

- review of well-integrity, annulus-pressure, cement, fluid-balance, cellar, drainage, membrane and pad-maintenance records;
- quantification of aggregate added, redistributed and removed, with locations, dates, thicknesses and reasons;
- pre-removal surface modelling, mapped excavation stages, membrane and subgrade inspection, and material sampling by location and depth;
- documented hold points and escalation procedures for unexpected fluids, gas, odour, staining, voiding, deformation or membrane condition; and
- waste classification, preservation of representative samples, chain of custody and post-deconstruction monitoring where behaviour persists.

Receptors and food-chain assessment

- mapping of crops, pasture, livestock access, ponds, watercourses, private water supplies, public paths, homes, roads, utilities and other receptors against the observed corridors;
- plant or pasture-tissue analysis only where environmental chemistry identifies a credible and bioavailable substance;
- livestock drinking-water, grazing, soil-ingestion and fodder exposure assessment where a pathway is demonstrated;
- veterinary or ecological review of attributable animal, fish or habitat patterns where supported by records; and
- milk, meat, organ, crop, feed or aquatic-organism testing only where the identified substance and exposure route justify food-safety assessment.

The food-chain sequence should remain explicit: first identify the environmental material; second establish mobility, bioavailability and exposure; third assess food or animal products where the preceding evidence warrants it. This avoids both premature claims of contamination and premature reassurance based on an untested upstream pathway.

Alternative-source mapping and controls

- matched control locations with similar geology, topography, drainage, land use and management history;
- mapping of agricultural treatments, road salt, drains, water and sewer infrastructure, construction materials, historic waste, peat extraction and old wells;
- review of pre-2011 imagery, maps, environmental records and available chemistry to establish baseline frequency and magnitude; and
- a documented comparison of each candidate explanation against observations that support, weaken or falsify it.

Conditions that would weaken or revise the hypothesis

The hypothesis should be weakened, narrowed or revised if robust evidence demonstrates that:

- the same patterns existed at comparable magnitude before 2011;
- matched unaffected catchments show equivalent lowering and manifestation sequences;
- the apparent LiDAR change disappears after robust co-registration and control for vegetation, water, construction and land management;
- chemistry, gas and radionuclide measurements at affected locations are indistinguishable from suitable controls;
- pale residues, staining, bubbling or vegetation effects are fully explained by ordinary local materials or biological processes;
- shallow groundwater levels and flow directions do not connect the locations;
- well, pad, drainage and integrity records exclude the proposed pathways;
- or another natural or anthropogenic explanation accounts for the spatial-temporal pattern more completely.

Conclusion

The present conclusion is limited but clear:

> The observed pattern is sufficiently coherent, temporally associated, measurable and mechanistically plausible to justify a connected hydrogeological, geochemical and ground-mechanics investigation, with receptor assessment where initial environmental testing identifies a credible pathway. It is not yet a proven causal account.