The Clay Research Group

RESEARCH AREAS

Climate Change ◆ Data Analysis ◆ Electrical Resistivity Tomography
Time Domain Reflectometry ◆ BioSciences ◆ Ground Movement
Soil Testing Techniques ◆ Telemetry ◆ Numerical Modelling
Ground Remediation Techniques ◆ Risk Analysis
Mapping ◆ Software Analysis Tools
Artificial Intelligence

January 2020
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Issue 176, January 2020

Estimates of Heave

We are fortunate that at the Aldenham site we can compare estimates of heave from a range of tests including oedometer and suctions, disturbed and undisturbed samples, with precise level measurements.

Unfortunately MatLab Limited are no longer trading, but the work undertaken by them, under the direction of their owner, Clive Bennett, provided the foundation to much of the research that followed at Aldenham.

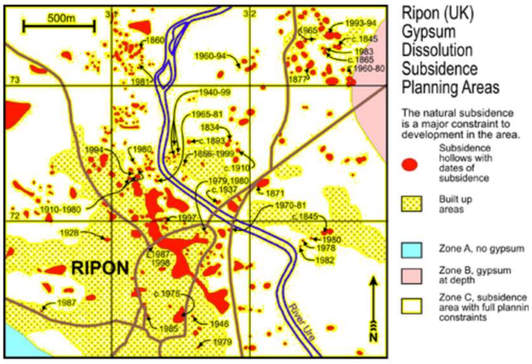
They funded the sinking of a series of boreholes between 2006 and 2008, carried out a wide range of soil tests and set up the precise levelling stations.

In this edition we compare predictions of heave from those investigations with precise level readings.

Sinkholes on TV

A repeat of the program television program "Sinkholes: Buried Underground" was aired on Channel 5 Select last month and touched on failures in Ripon. The British Geological Survey have carried out extensive work mapping the risk in this area and full details are available from their web site (including the image below) at:

https://www.bgs.ac.uk/research/engineeringGeology/shallowGeohazardsAndRisks/sinkholes/riponFeb2014.html



Visitors to CRG Web Site

The site attracts between 70 – 80 visitors a day on average and over 16,000 hits a month. The rate has remained fairly constant over the last 10 years, with the predominant download being the monthly newsletter followed by the paper 'Site Investigations and Soil Testing' describing investigations undertaken at Aldenham and published in November 2007.

Contributions Welcome

Thanks to contributors who have spent time putting together articles on a range of topics over the last 13 years or so. Articles, comments and so forth are always welcome. Please Email us at clayresearchgroup@gmail.com.

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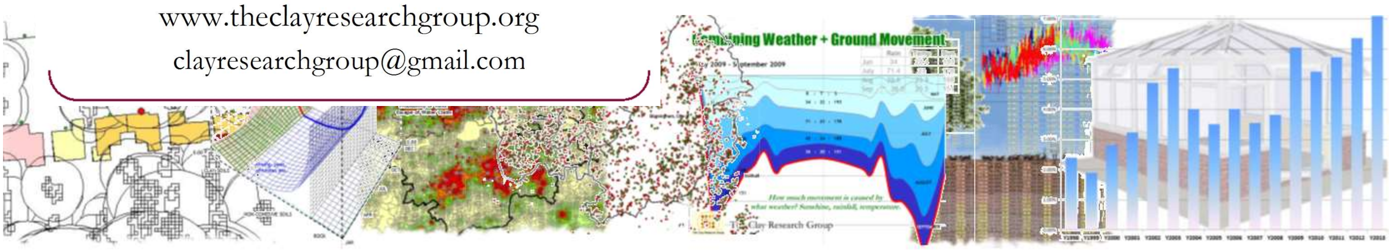

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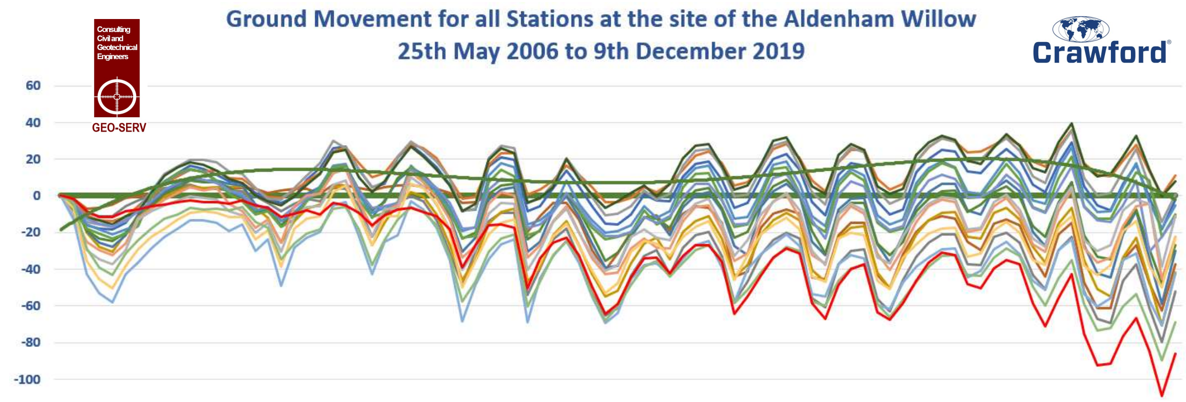
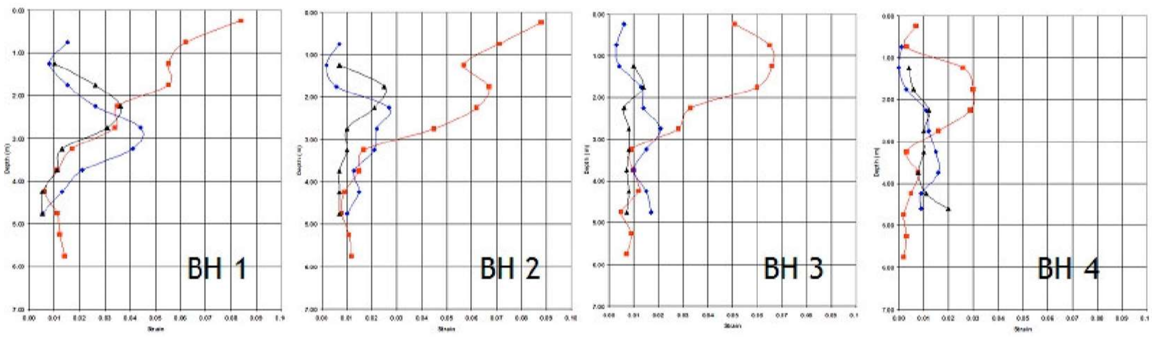
Aldenham Willow – Precise Levels

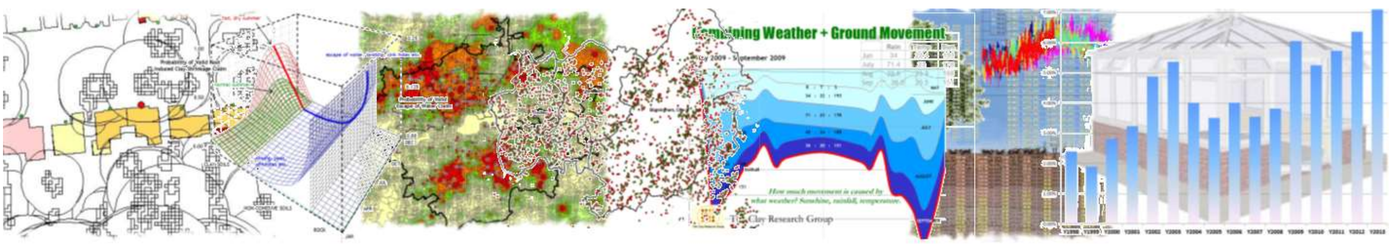
Below, an update to the precise level survey undertaken by Geo-Serv Limited at the site of the Aldenham willow and funded by Crawford & Co., reveals a continued periodic signature with stations furthest away from the tree subsiding most and stations nearest the tree showing gradual recovery.



MatLab Limited installed level stations, a datum and carried out extensive site investigations and soil testing at their own cost over a period of time. The results added to our understanding of root induced soil drying as can be seen in the graphs below, which reveal decreasing desiccation with distance from the tree.



The above graphs plot strains measured using the oedometer and compare the results of disturbed and undisturbed samples, revealing partial rehydration over the twelve-month period. Red lines plot May 2006 and blue and black graphs, June 2007). For borehole locations see following page.



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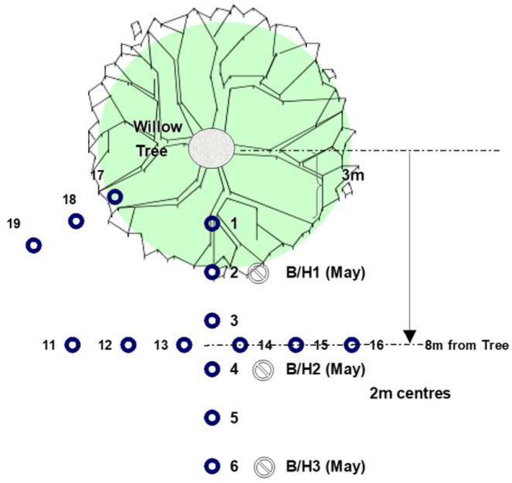
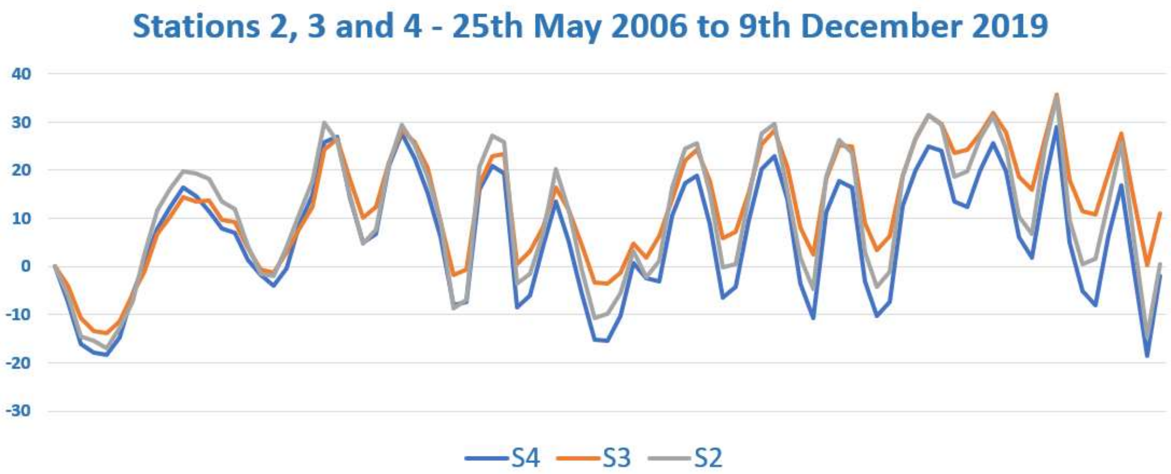
Precise Levels, Estimates of Heave and Weather Data

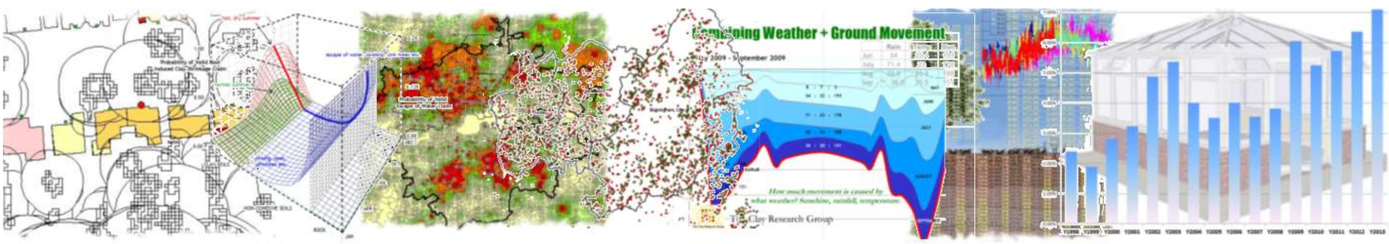
In this article we look at estimates of heave from soil samples retrieved in May 2006, March 2007 and April 2008, comparing them with actual ground movement that has taken place by referring to precise level data for station 2 nearest to the site of the borehole. On page 6 ground movement profiles are overlaid onto a range of weather data including Soil Moisture Deficit (SMD), temperature, rainfall and hours of sunshine to see if there is a link between them.



There are of course difficulties in matching the various datasets. SMD is recorded weekly, whereas weather data is collected monthly and the nearest weather station available from Met Office records is Heathrow – some 22km distant. Precise levels were taken towards the end of each month with the exception of February and April 2008, which were omitted.

Below, a graph of ground movement for the stations 2, 3 and 4 for the monitoring term extending from 25th May 2006 to 19th December 2019.





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Precise Levels and Weather Data

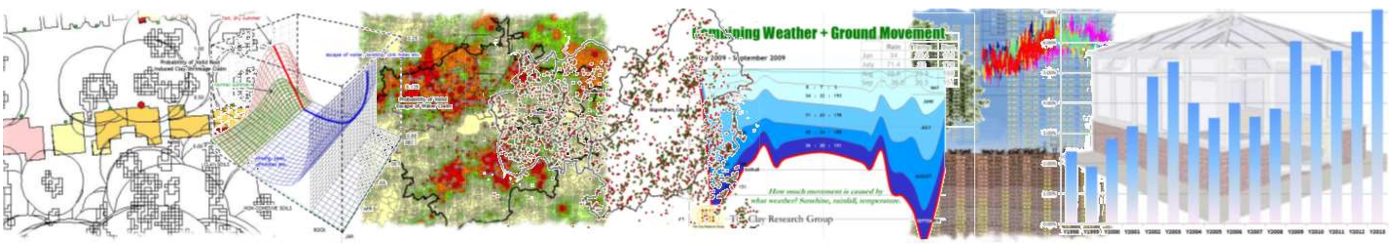
Levelling stations 2, 3 and 4 follow similar profiles over time as can be seen in the figure below. Station 2 is around 5mtrs from the tree and corresponds with the location of BH1. The objective of this exercise is to assess the 'accuracy' of estimates of heave and for this initial assessment, disturbed oedometer samples have been used.

As the tree is not going to be removed and full rehydration is unlikely in its presence, the various estimates of total heave on expiration of the deficit can't be verified. Even if the tree were felled, rehydration could take 10 years or more.

Instead, estimates of ground movement and precise level records over specified periods (i.e. the dates of the site investigations shown in the illustration above – May 2006, June 2007 and April 2008) are compared.

Did the estimates of swell that were predicted based on soil tests match movement that was subsequently recorded using precise levels over the intervals shown? If the estimated heave in May 2006 was 78mm, and in June 2007, 47mm, did precise levels record upward movement of 78 – 47 = 31mm?

The exercise provides an idea of the 'accuracy' of heave estimates made at the time the soil tests were undertaken using oedometer testing and disturbed samples.



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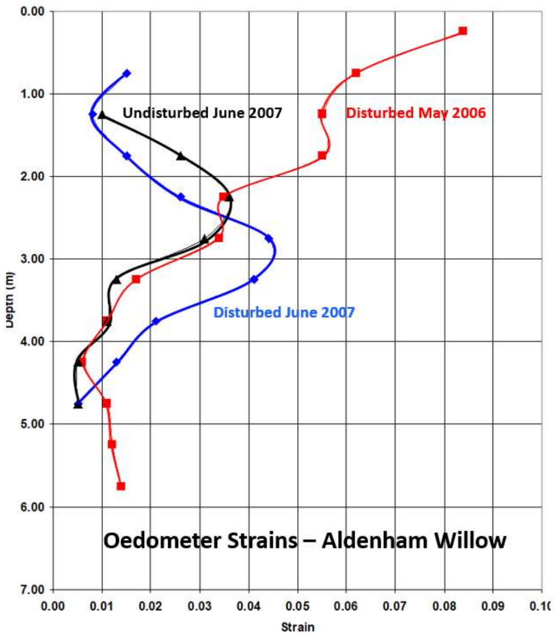
Aldenham Willow - Soil Strains May 2006 and June 2007

A range of samples and tests were undertaken (filter paper suctions, oedometer strains from disturbed and undisturbed samples, moistures, liquid and plastic limits) and a snapshot is shown right. These results were taken from a borehole sunk 4mtrs away from the willow.



The oedometer profile for 2006 (a surge year) is shown in red with high strains at shallow depth. Desiccation extends to 4mtrs below ground level in all cases.

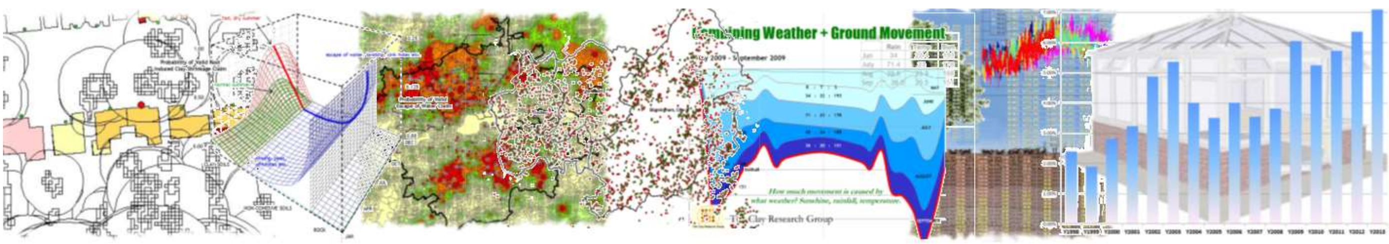
Disturbed and undisturbed samples retrieved in June 2007 (blue and black) revealed a dissipating profile reflecting rehydration over the preceding year.

	Estimates of Heave from soil tests described			Comparing Estimates with Outcomes					
				estimated	estimated	actual	actual	diff	diff
Sample Type	May-06	Jun-07	Apr-08	Jun-07	Apr-08	Jun-07	Apr-08	Jun-07	Apr-08
OED (disturbed)	78	47	56	31mm	22mm	13.5mm	28mm	17.5	-6
Filter (disturbed)	101	55	56	46mm	45mm	13.5mm	28mm	32.5	17

Above, a table comparing estimates of swell from soil results with actual movement recorded using precise levels. For example, if the predicted heave using disturbed filter papers was 101mm in May 2006, and 55mm in June 2007, we might expect 101 – 55 = 46mm of heave to have taken place. In fact, precise levels reveal a recovery of only 13.5mm in June. Less than a third of the estimated movement.

Taking another example, looking at the results for disturbed oedometer samples, estimated heave was 78mm in May 2006, falling to 56mm in April 2008, suggesting a recovery of around 78 – 56 = 22mm might be recorded in that term. In fact, precise levels revealed recovery of 28mm – a minor under-estimate of 6mm. Differences between estimates of heave and precise levels are in the range of 32.5mm to -6mm, with oedometers delivering the best results.

Station 2 recorded maximum recovery in May 2018, rising 35.2mm above its starting point in May 2006. From the data above it can be seen that most estimates of swell based on soil tests are twice the measured outcomes, suggesting that station 2 may be fully rehydrated in the winter, and is now exhibiting 'normal' seasonal movement.



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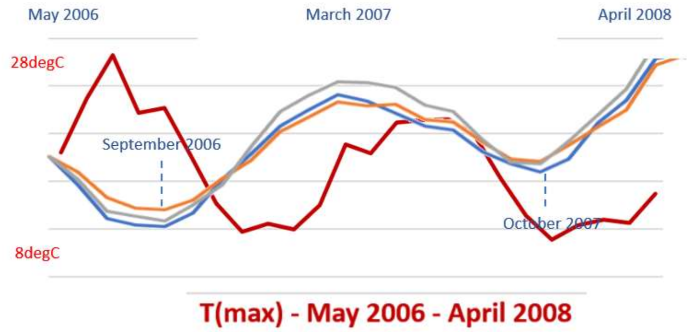
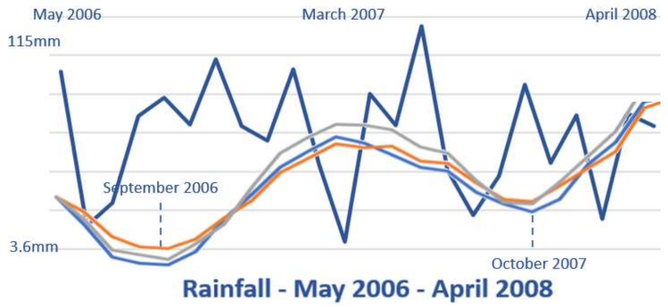
Precise Levels and Weather Data

Ground movement profile from page 4 superimposed onto the SMD profile for the period May 2006 to April 2008. It can be seen that there is a delay between SMD dropping and ground subsidence with peaks in the latter appearing in September 2006 and October 2007.

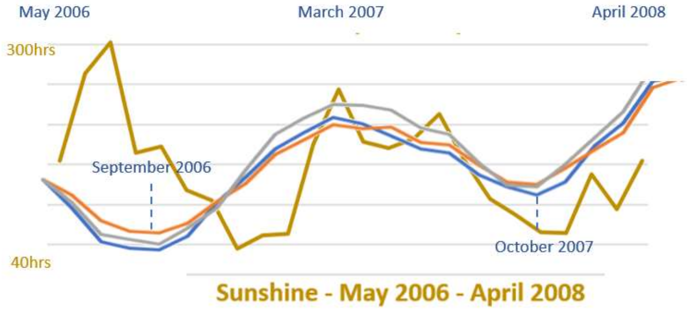
There is a clear visual link between ground movement and temperature as might be expected. As the temperature increases around June/July, so the ground subsides – after a delay of around 3 months or so.

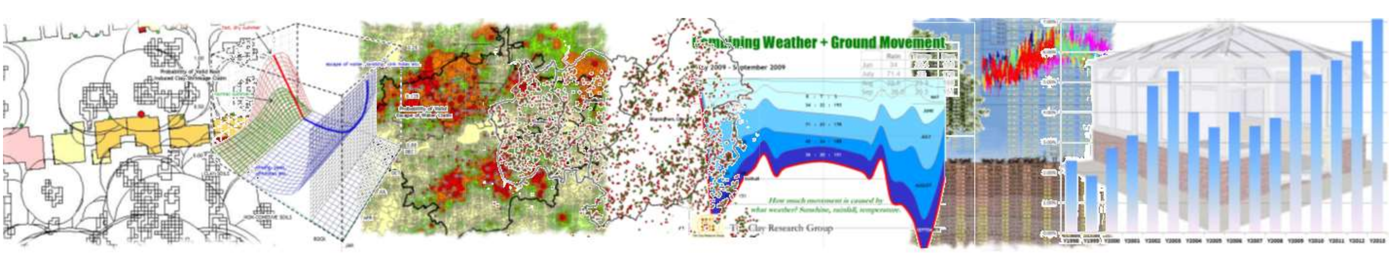




The link between ground movement and rainfall is less clear. The rainfall appears intermittent and it is difficult to see a 'cause and effect' pattern, which may in part be due to the difference in how the data are gathered.

As with the temperature record, there is a good visual link between hours of sunshine and ground movement





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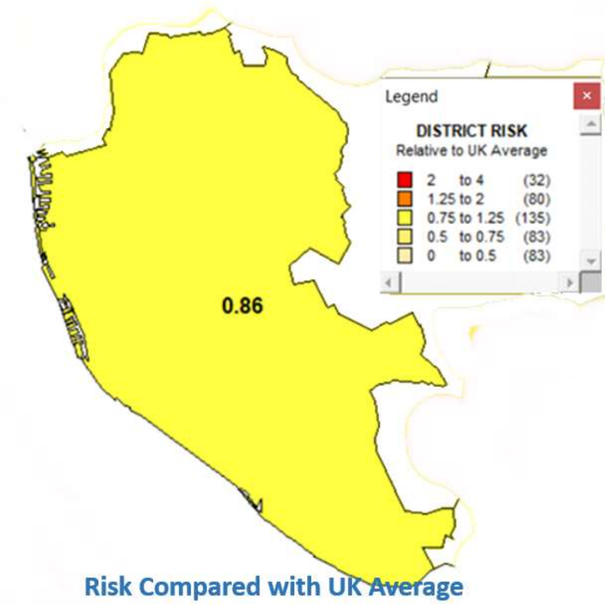
Subsidence Risk Analysis – Liverpool

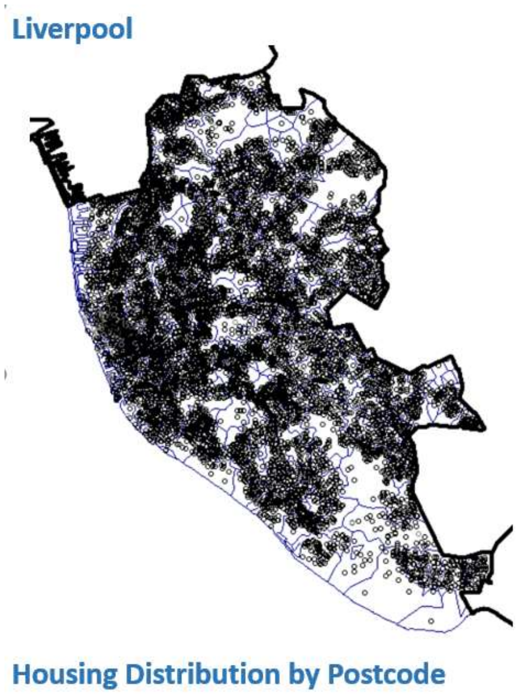
Liverpool has an area of around 116km^2 and population of just over 550,000.



Liverpool has an estimated population of over 550,000 and an area of 116km^2.

Mapping housing distribution across the city (below, using full postcode as a proxy) helps to clarify the significance of the risk maps on the following pages. Are there simply more claims because there are more houses?

Using a frequency calculation (number of claims divided by private housing population) the relative risk across the district at postcode sector level is revealed, rather than an absolute 'count of claim' value.

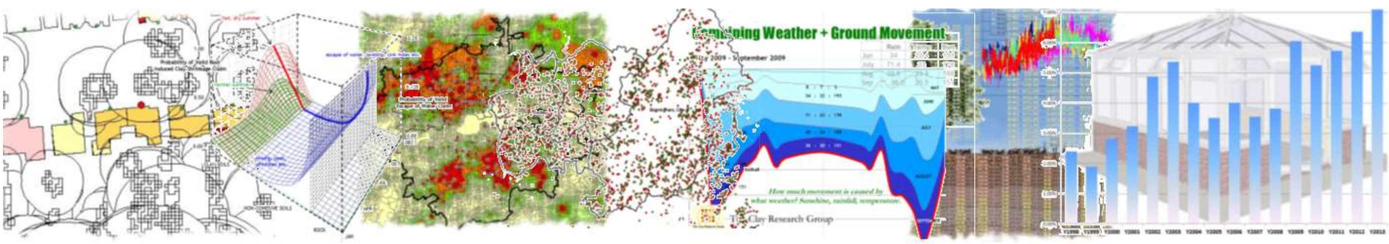


Distribution of housing stock using full postcode as a proxy. Each full postcode in the UK covers on average 15 houses, although there are significant variations.

Districts are rated for the risk of domestic subsidence as shown on the above map in relation to the UK district average. The highest risk rating on rating scale is a value of 4. Liverpool is rated 0.86 on this scale.

The value translates to a risk of 0.215 on a normalised scale of 0 – 1.

In our 'rank order of risk' table of UK districts for subsidence claims frequency Liverpool comes 214th out of 413 UK districts



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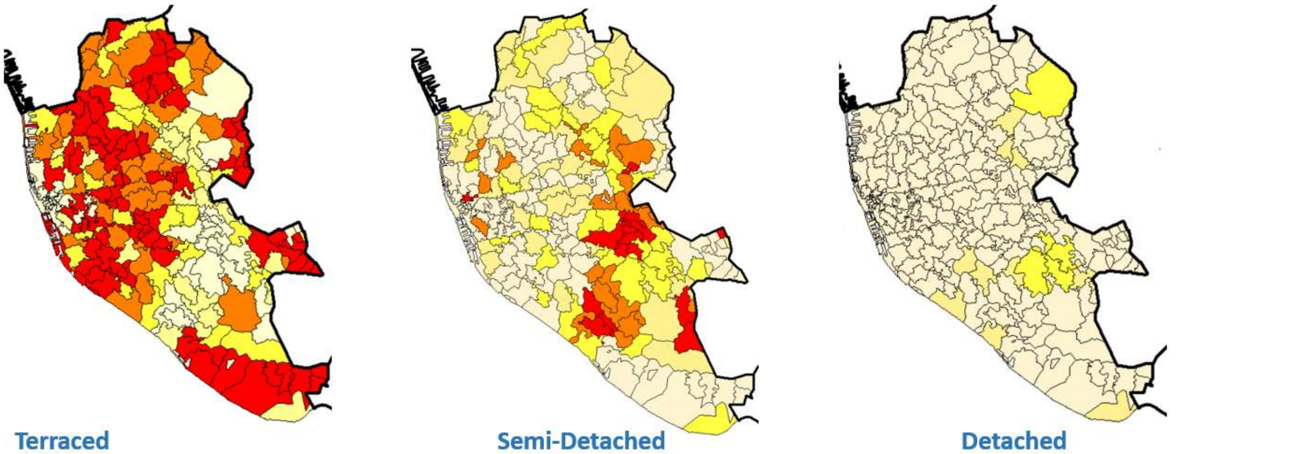
Liverpool - Properties by Style and Ownership

Below, the general distribution of properties by style of construction, distinguishing between terraced, semi-detached and detached. Unfortunately, the more useful data is missing at sector level – the age of the property. As we have seen from earlier studies, risk increases with age.

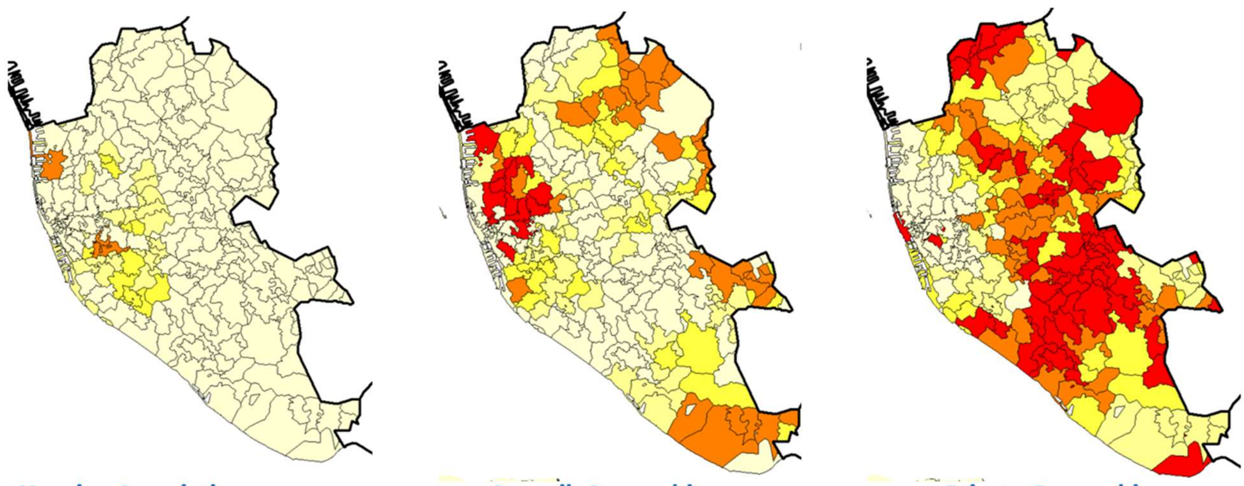
Distribution by House Type



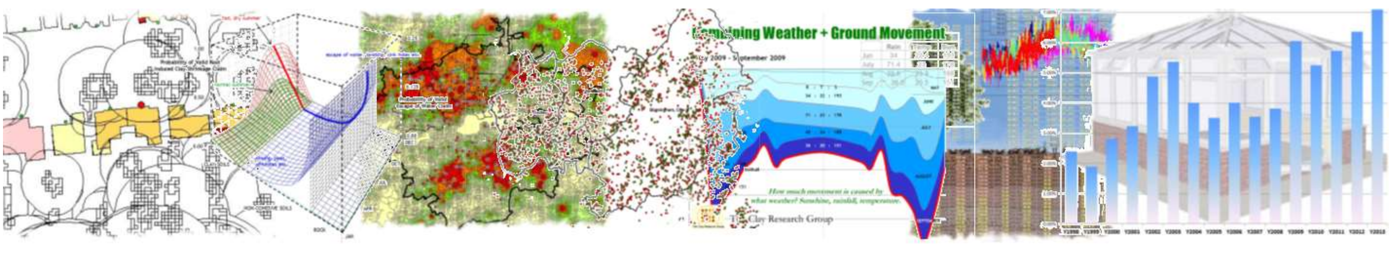
Terraced | Semi-Detached | Detached

Distribution by ownership is shown below, revealing a high population of privately-owned properties across the borough and a high concentration of terraced houses.

Distribution by Ownership



Housing Association | Council Ownership | Private Ownership



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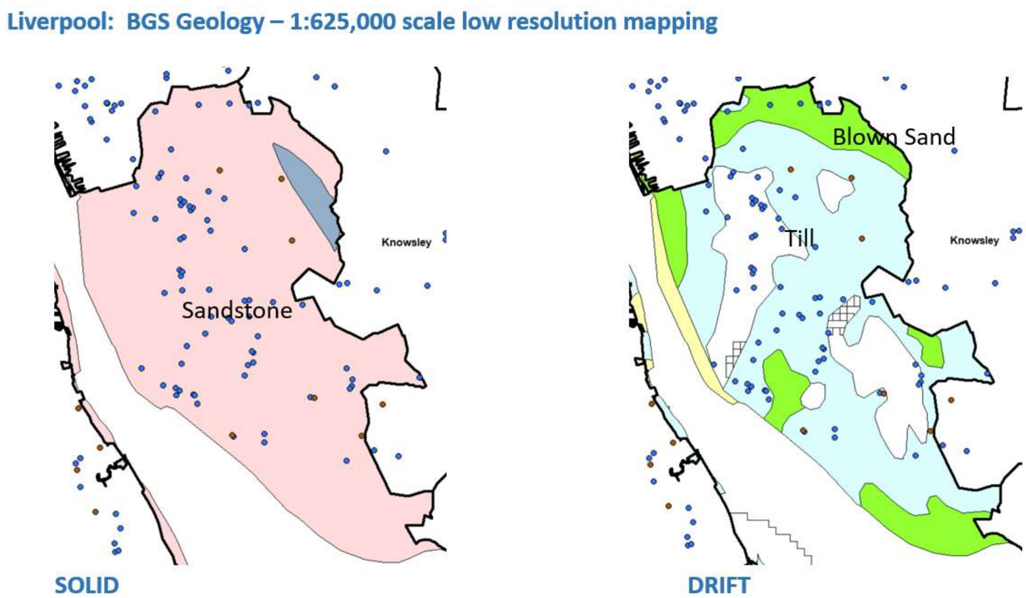
Subsidence Risk Analysis - Liverpool

Below, extracts from the British Geological Survey maps showing the solid and drift series. View at:

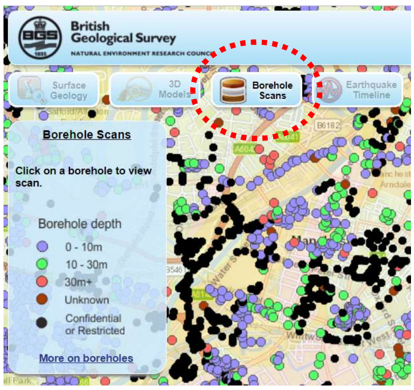
http://mapapps.bgs.ac.uk/geologyofbritain/home.html

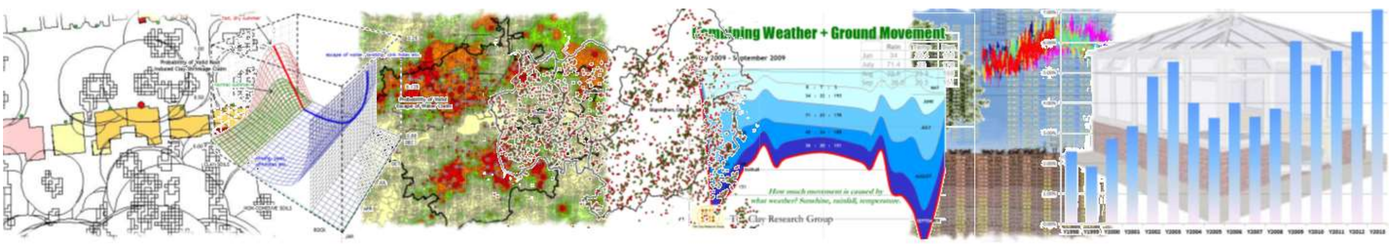


See page 12 for a seasonal analysis, which reveals that the probability of a valid claim being due to clay shrinkage in the summer is very low - far less than due to an escape of water and falling further in the winter. Throughout the year the probability of a claim being declined is higher in the summer.

The above BGS web site also provides access to borehole data providing information on the depth and thickness of the strata – see screenshot right.

The colour of the dot relates to the depth of borehole and selecting one returns a pdf of the original log.





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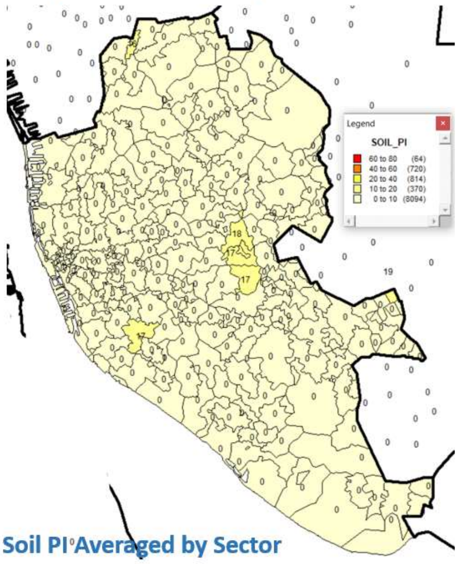
Liability by Season and Geology

Below, determining if there is a link with the underlying geology by making reference to the CRG 250m grid (below) plotting soil by PI obtained when investigating claims.

Liverpool – Soil Plasticity Index

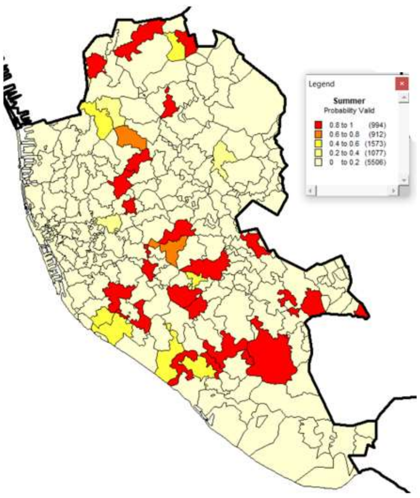


Soil PI Averaged by Sector

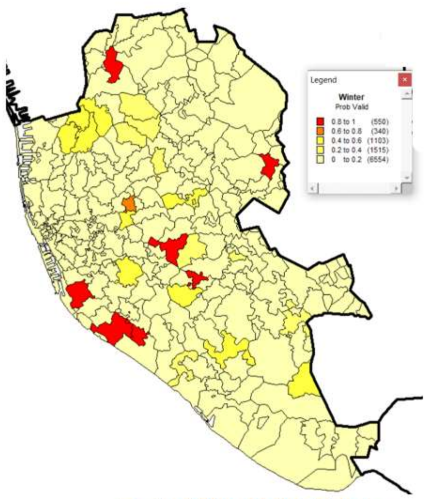
Very few sectors have a significant clay content as can be seen on the CRG geological map. The results of actual investigations have been plotted on a 250m grid. The results show only four sectors have a significant recorded clay content, and in those sectors, the PI is less than 20%.

Below, the probability of whether a claim is likely to be valid or declined (irrespective of cause) by season. In the summer there appears to be several concentrated areas whereas in the winter, the numbers are higher across the area.

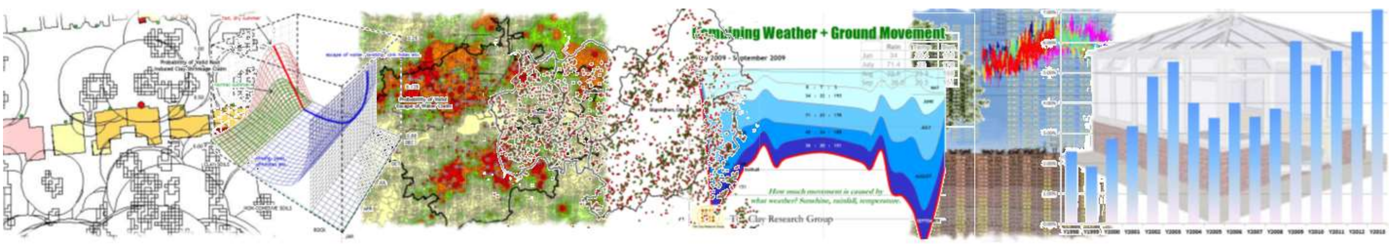
Liverpool



Probability Valid, Summer



Probability Valid, Winter



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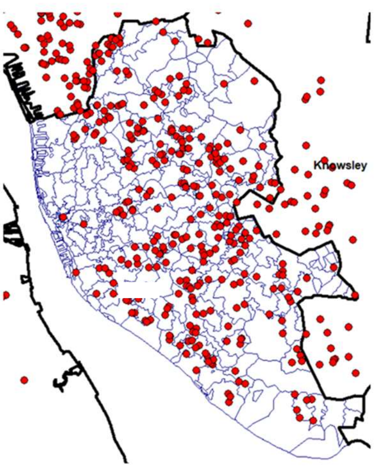
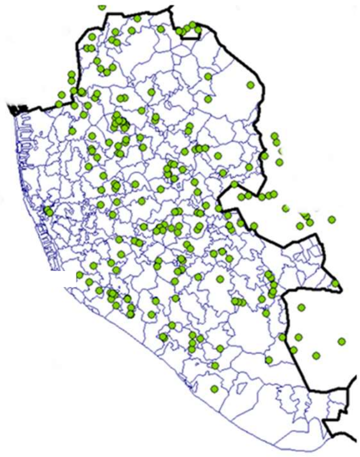
Liability by Sector. Escape of Water and Council Tree Claims Distribution

Liverpool – Liability Distribution



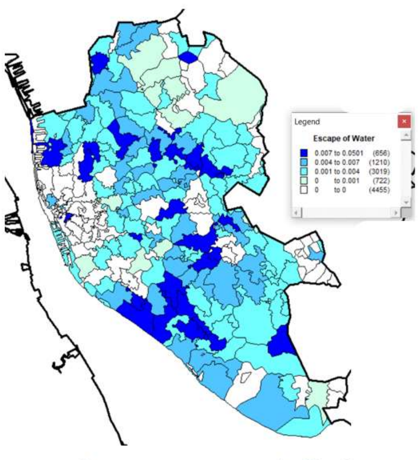
Declinatures



Valid Claims

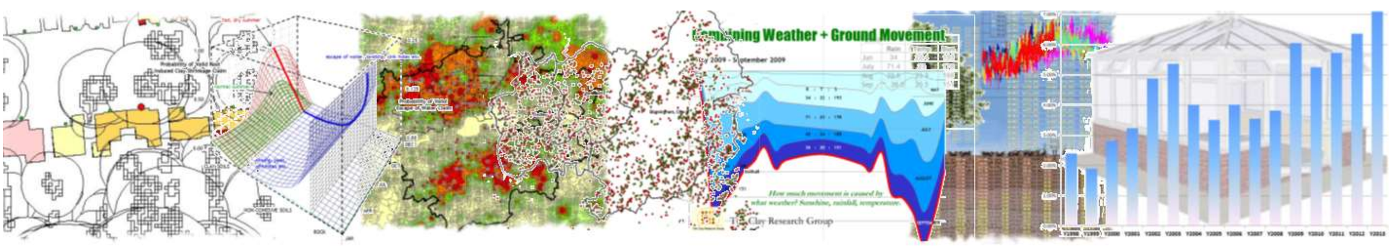
Above, mapping liability and plotting distribution of valid and declined claims for the sample size shown, not taking into account any seasonal influence. Below left, mapping the frequency of Escape of Water claims from the sample reflects the primarily non-cohesive drift deposits – Till, sand and sandy gravels. Below, right, dots on the 'Council Tree Claims' map, represent properties where damage has been attributable to vegetation in the ownership of the local authority to determine if there is what is termed a 'hot spot'. The low count in the sample we hold reflects the variable, non-cohesive, geology.

Liverpool – Postcode Distribution



Escape of Water Frequency Distribution

Street Tree Claims



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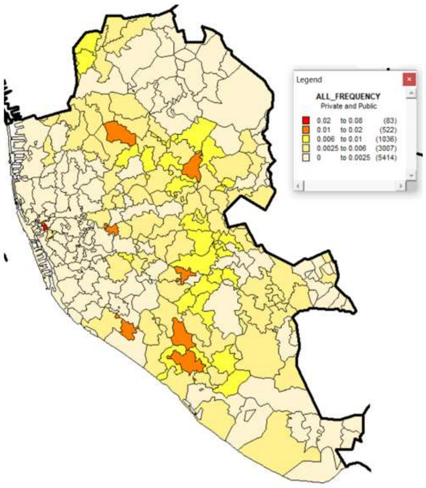
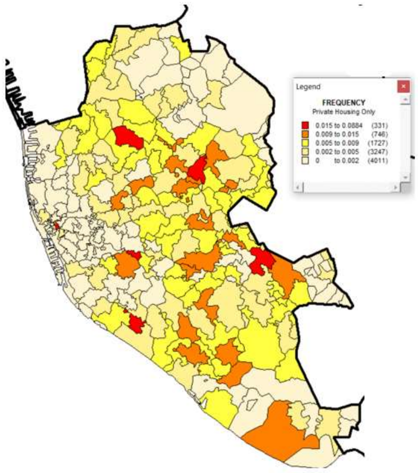
Liverpool - Frequencies, Count & Probabilities

Liverpool - Postcode Sector Subsidence Risk by Ownership



Combined Public and Private Frequency



Private Only

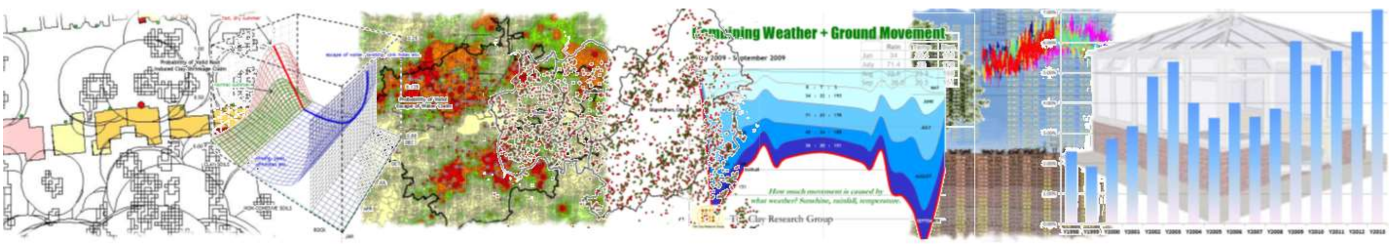
Above, private housing plot links risk with the CRG geological map revealing the higher risk when ownership is taken into account. Below, the figures reveal a borough with a modest seasonal-related risk. Valid claims have a high probability of being water related – escape of water from drainage predominantly, followed by leaking water services etc.

Valid claims throughout the year are more than 10 times likely to be due to EoW. The chances of a claim being declined in the summer are high, approaching 70%, and in the winter, the repudiation rate drops to just over 20%.

The district illustrates the significant differences between boroughs, dependent on their geology. In this case, where the superficial drift deposits dominate, it gives a valuable clue to (a) their composition and (b) their thickness.

Liability by Season - Liverpool

District	valid summer clay	valid summer EoW	Repudiation Rate (summer)	valid winter clay	valid winter EoW	Repudiation Rate (winter)
Liverpool, City of	0.022	0.288	0.69	0.06	0.72	0.221



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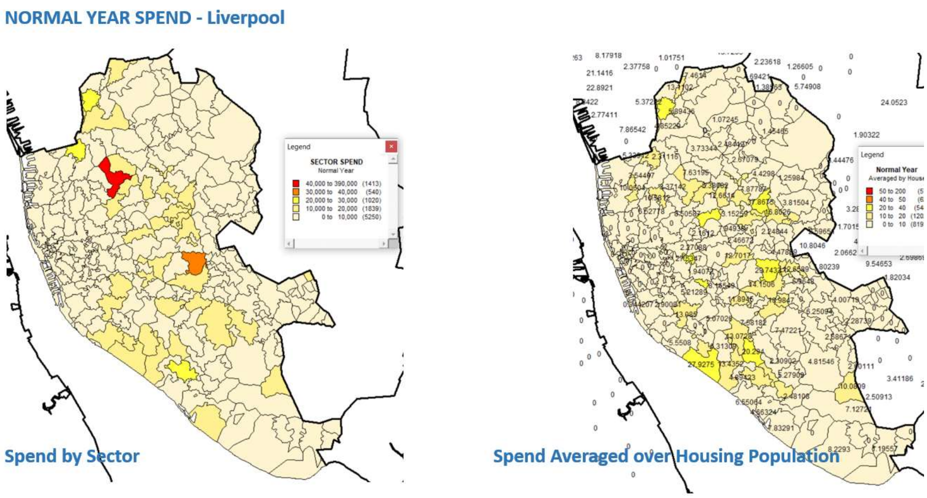
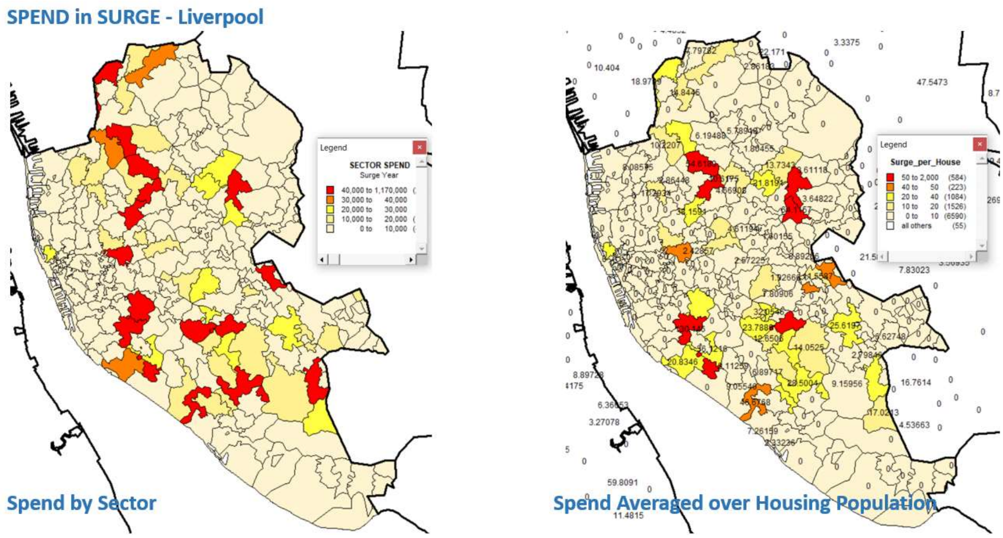
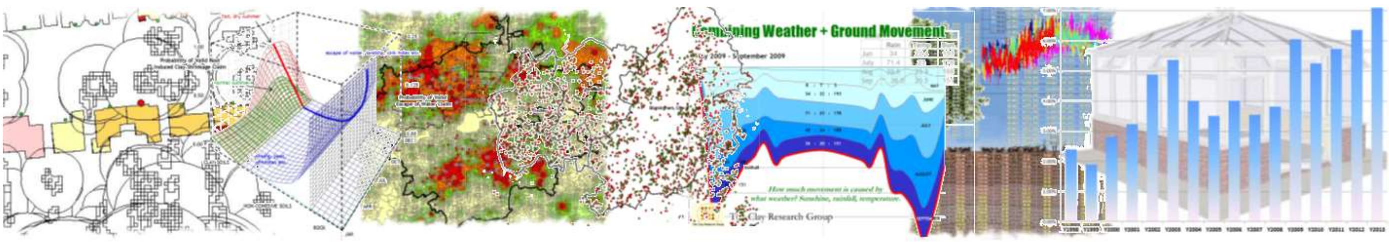
Aggregate Subsidence Claim Spend by Postcode Sector and Household to Derive Risk and Premium in Surge & Normal Years

The maps below show the aggregated claim cost from the claim sample per postcode sector for both normal (top) and surge (bottom) years. The figures reflect the study sample and will vary by season, year and insurer's exposure and distribution.



As mentioned in previous editions, not all areas see an increase in cost associated with surge, reflecting the variable geology. It will also be a function of the distribution of vegetation and age and style of construction of the housing stock. The image to the left in both examples represents sector spend from the study sample and the figures to the right, sector spend averaged across private housing population to derive a cost per house.





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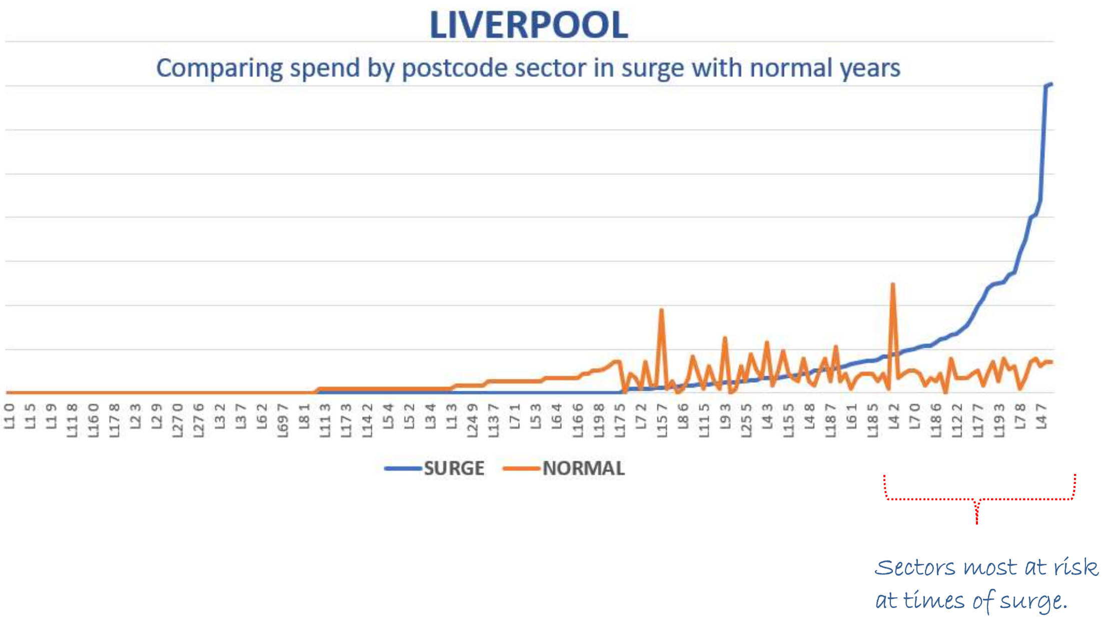

Identifying the variable risk across the district between normal and surge years by postcode sector. Divergence between the plots indicates those sectors most at risk at times of surge.

In making an assessment of risk, housing distribution and count by postcode sector plays a significant role. One sector may appear to be a higher risk than another based on frequency, whereas basing the assessment on count might deliver a different outcome. This can also skew the assessment of risk related to the geology, making what appears to be a high-risk series appear less of a threat than it actually is.