British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Controls on the Distribution of Drift Filled Hollows in London

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Engineering Geology of Scour Features
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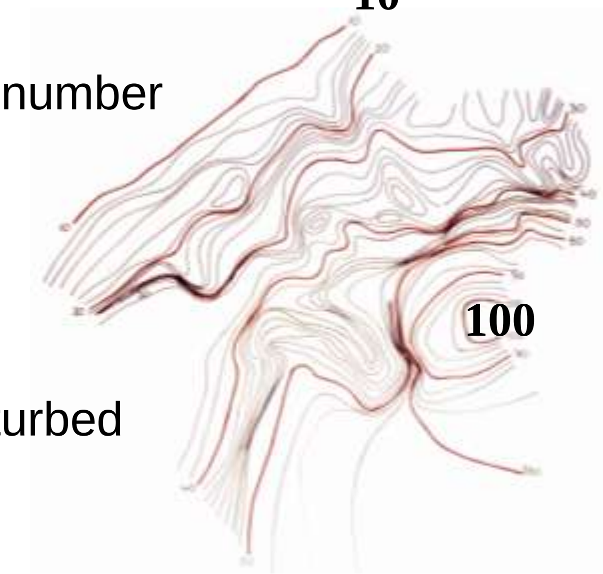
Outline

1. Why study Drift-Filled Hollows (DFHs) ?
2. Controls on the distribution of Drift-Filled Hollows in London
3. Developing a Hazard Susceptibility Map for Drift-Filled Hollows
4. Limitations
5. Better Process Understanding

Why produce a susceptibility map for Drift – Filled Hollows?



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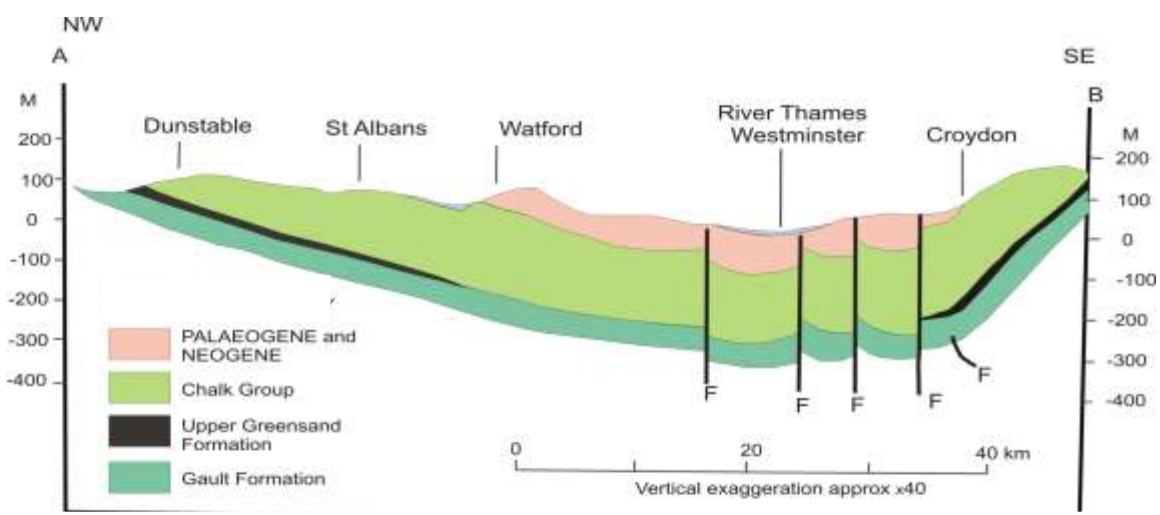
- Engineering works in central London have unearthed a number of these features.
- Can be up to 500 m wide and more than 60 m in depth.
- DFH can extend deep into the bedrock geology
- Generally in-filled with superficial deposits – may be disturbed and sometimes highly disturbed bedrock.

- Provide a map with the potential location of difficult ground conditions associated with DFH's:
    - ⇨ Reduce the potential for unforeseen ground conditions
    - ⇨ More effective site investigation design.
    - ⇨ Reduce risk of project over-run and additional costs

Geology of the London Basin

Age	Group	Principal succession
Quaternary		Alluvium
		River Terraces
Palaeogene	Thames	London Clay Formation
		Harwich Formation
	Lambeth	Reading Formation
		Woolwich Formation
		Upnor Formation
		Thanet Sand Formation
Cretaceous	Chalk	Newhaven Chalk Formation
		Seaford Chalk Formation
		Lewes Chalk Formation



Royse, 2010

Implications for engineering

The key implications:

- Variability in infill materials and ground conditions
- Potential for ground disturbance associated with DFHs
- Potential contaminant pathway to deep groundwater.

Characteristics noted in borehole descriptions:

1. May be associated with a thick zone of bedrock mélange, which may comprise bedrock from the London Clay, the Lambeth Group, the Thanet Formation or the Chalk.
2. The bedrock strata may be elevated above that of the area.
3. Fragments of chalk have migrated towards the surface e.g. At Blackwall chalk blocks have been encountered up to 15m above chalk rockhead.
4. In some of the features downward migration of glauconitic sand (derived from the Palaeogene strata) and flint pebbles were observed.
5. Some features in-filled with channel deposits or lacustrine sediments

Drift-Filled Hollows - what are they ?

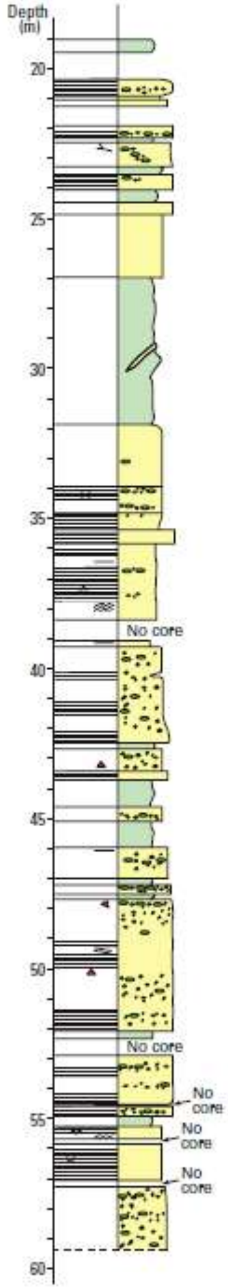
The process understanding (how these things were formed) is very unclear

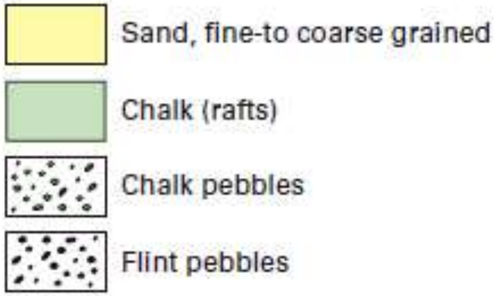
Different processes have been proposed in the literature:

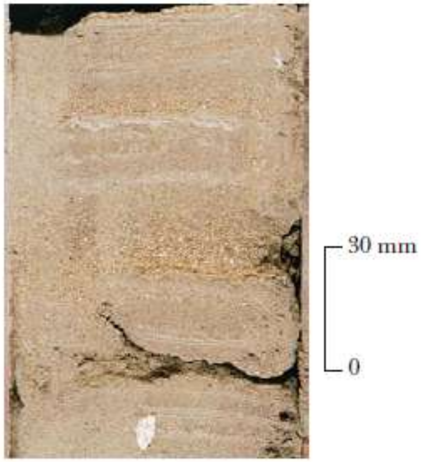
- Scour hollows
- Pingos (open and closed)
- Dissolution features
- Frost heave and ice wedges
- Diapirism

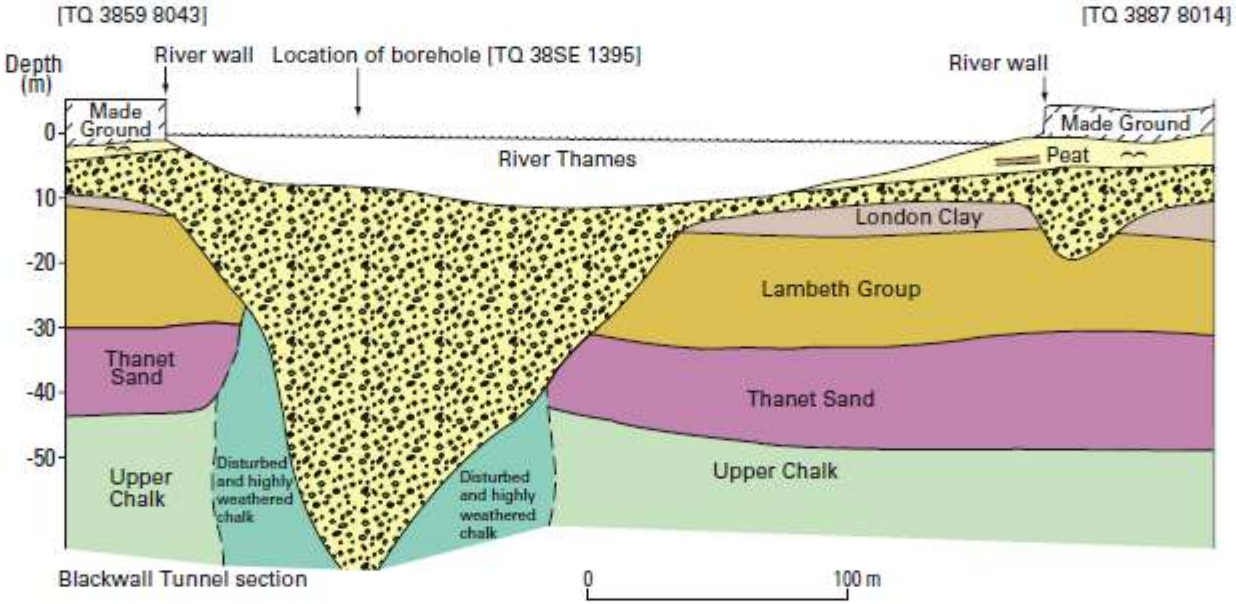
- Combination of processes ?
- Can we distinguish the different characteristics?
- Map of DFH susceptibility doesn’t distinguish different types

Drift-Filled Hollows - what are they ?
Blackwall Tunnel – Pingo?







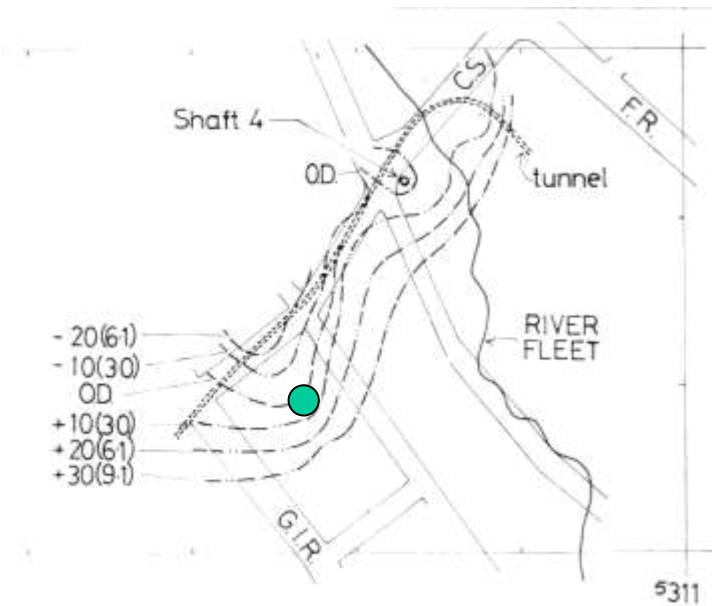


(Geology of London, BGS Special Memoir, Ellison et al., 2004)

Drift-Filled Hollows - what are they ?

Grays Inn Road, London (Berry, 1979)

BERRY, F G. 1979. Late Quaternary scour-hollows and related features in central London. *Quarterly Journal of Engineering Geology*, Vol. 12, 9-29.

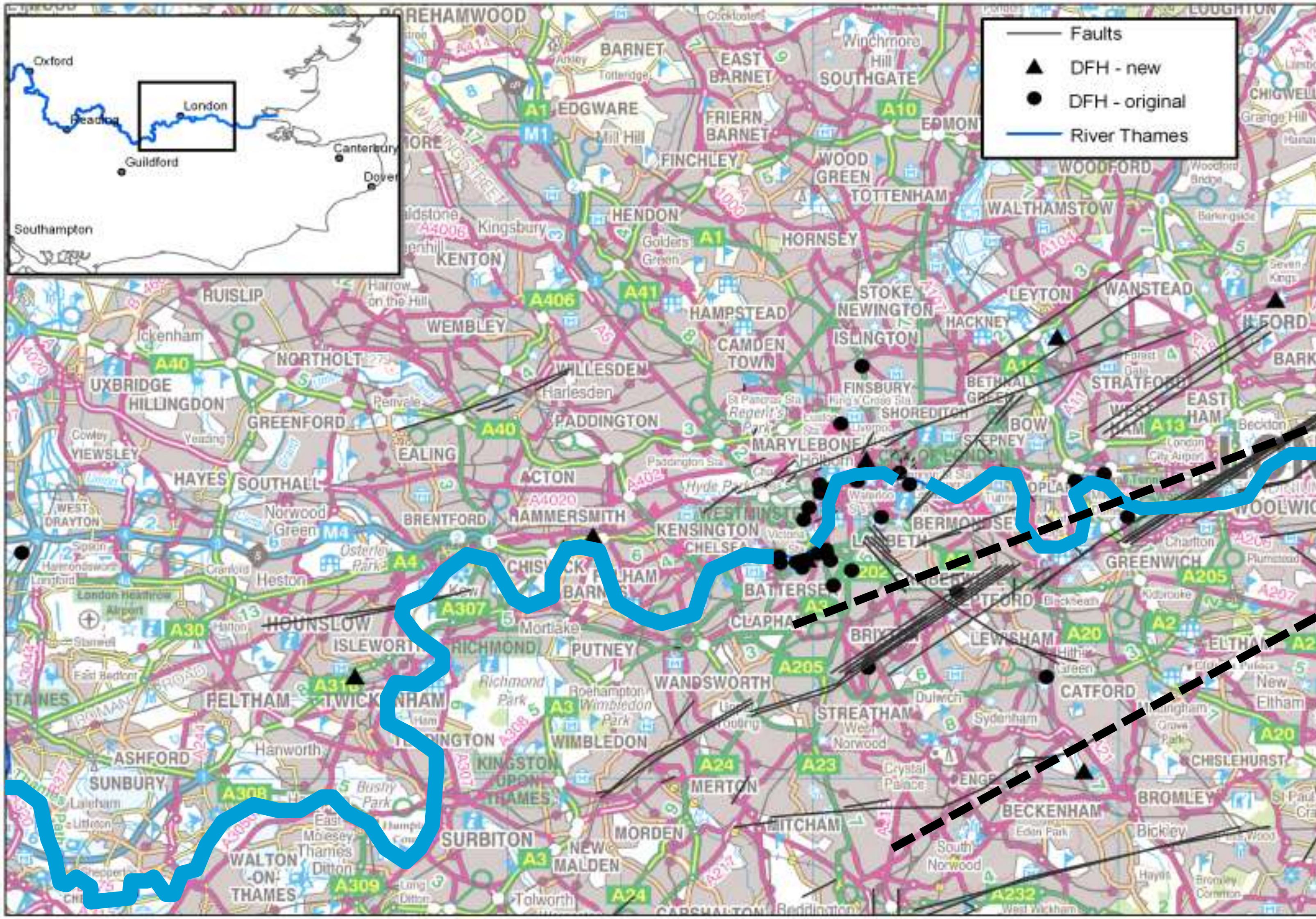


- Fine-grained alluvial sequences with fossils with silts and clays reworked from London Clay
- Densely packed gravels
- Over-consolidated reworked London Clay
- Scour feature infilled with channel deposits, over-bank sediments or lacustrine sediments?

Times Building excavations (New Printing House Square)

Photographs by Frank Berry

Location of Drift-Filled Hollows in London



Developing a Hazard Susceptibility map

Part 1 : Defining the criteria for the map

- Examined the geological and hydrogeological parameters common to the observed DFH
- Related these back to criteria used in Hutchinson's work

1. *Situated in valleys, close to the valley floor.*
2. *Associated with the feather edge of the London Clay*
3. *Artesian groundwater conditions (Simpson et al., 1989). (actual uplift pressures required to generate uplift of the Lambeth Group were higher than the Historic Maximum Value.*
4. *Unloading of the overburden material (by scouring) may have facilitated pore water pressure breaching of the London Clay.*

Hutchinson (1980, 1991)

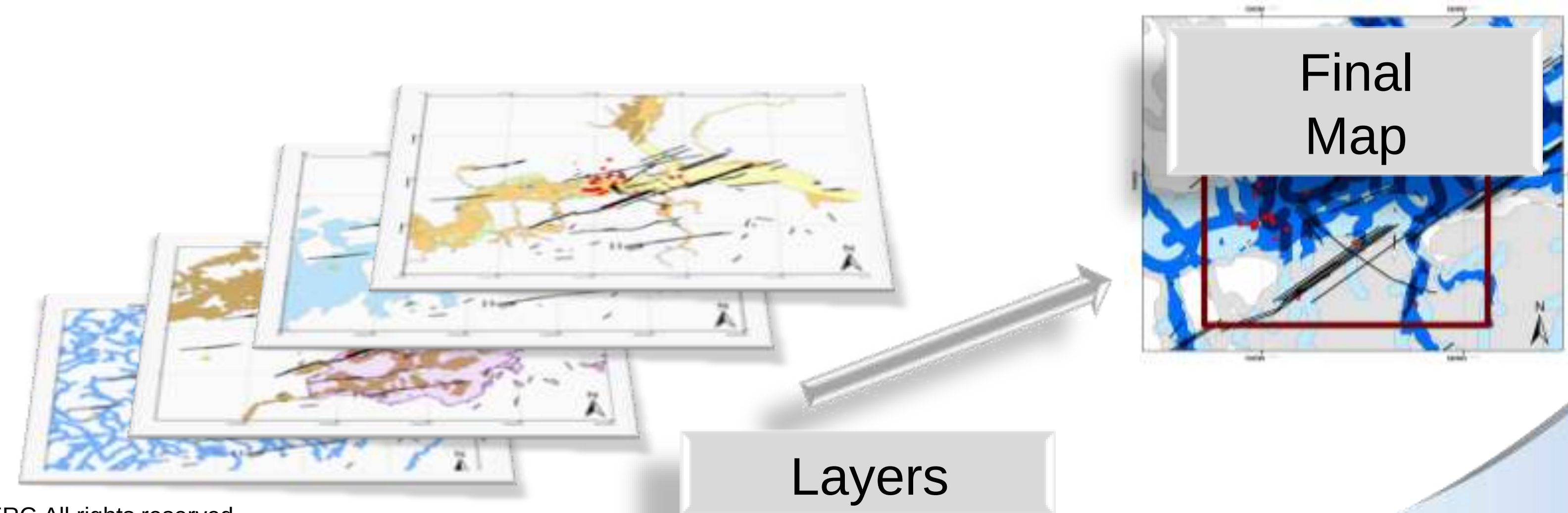
Criteria used to create the GIS map layers

1. Within a zone of former artesian groundwater conditions

2. Where the London Clay is less than 35 m thick or where the Lambeth Group is clay-rich

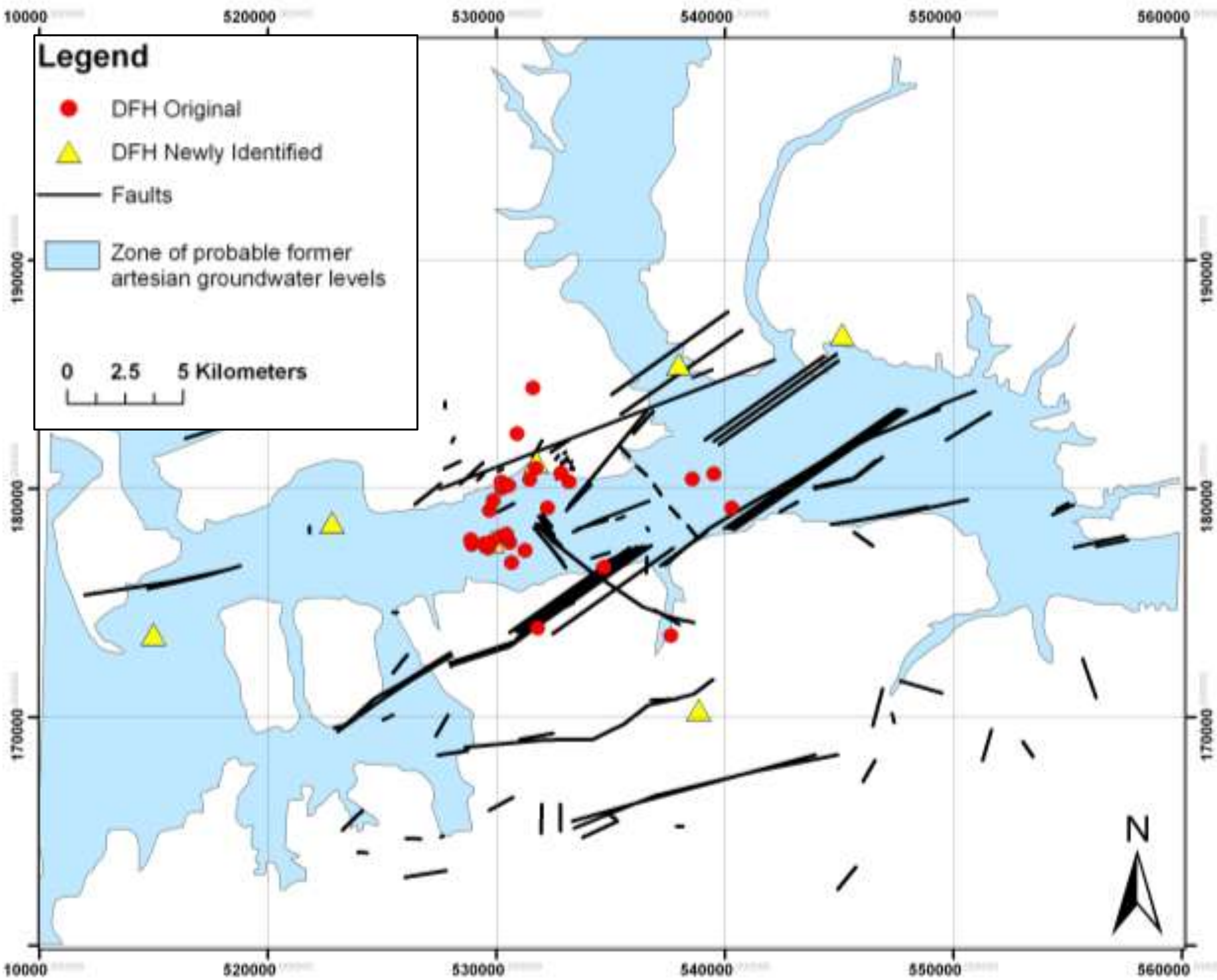
3. Within 300m of the river network

4. Beneath the Kempton Park Gravel Member



Developing a Hazard Susceptibility Map

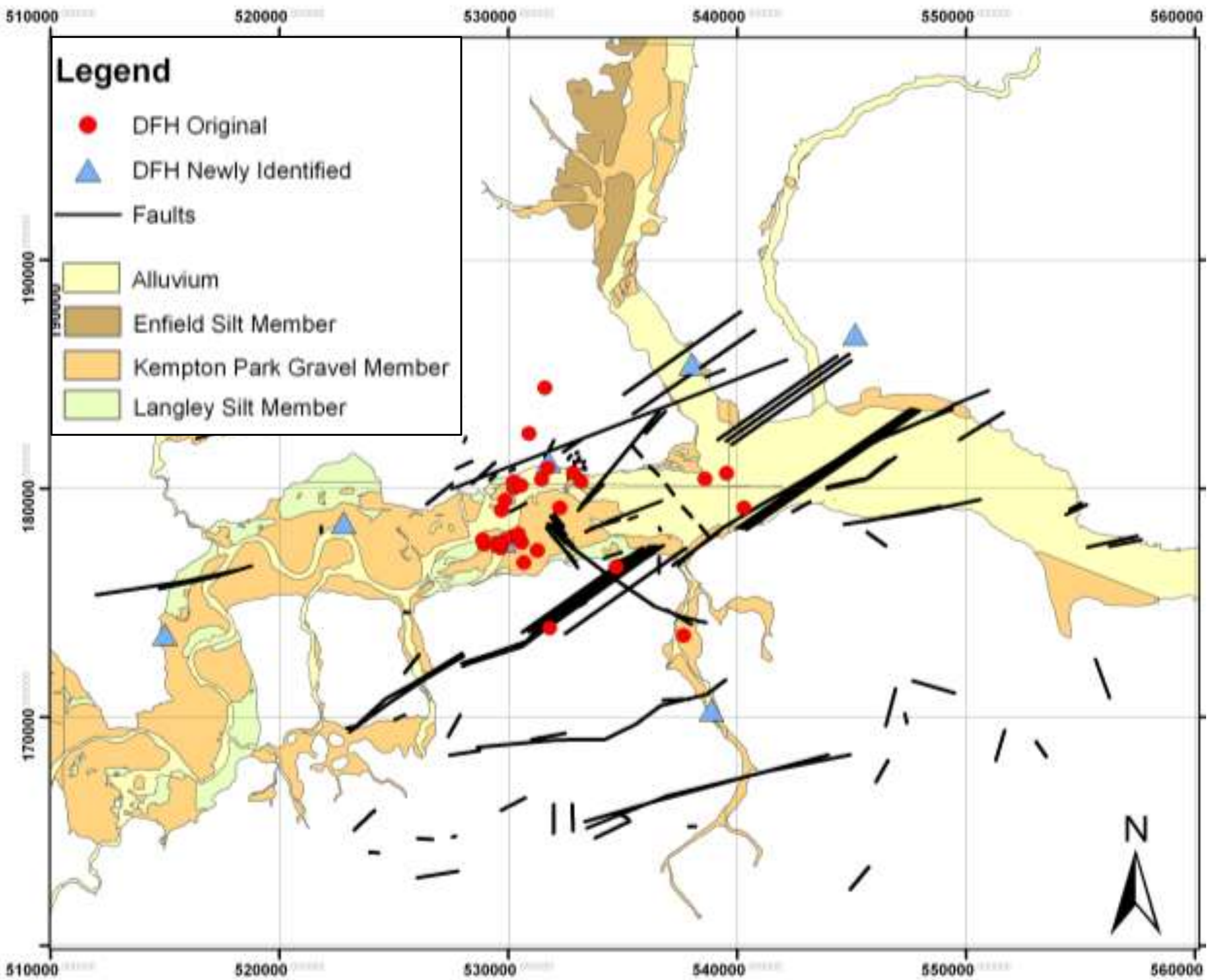
1. Artesian groundwater levels



- Can't tell what the GW pressure was like when DFH formed
- Old water well data from 1800s held by Water Resources Board/IGS.
- They combined ground elevation data ➔ Approx map of artesian conditions
- Assumed to approx Devensian conditions
- Only 4 DFHs do not fall in the zone

Developing a Hazard Susceptibility Map

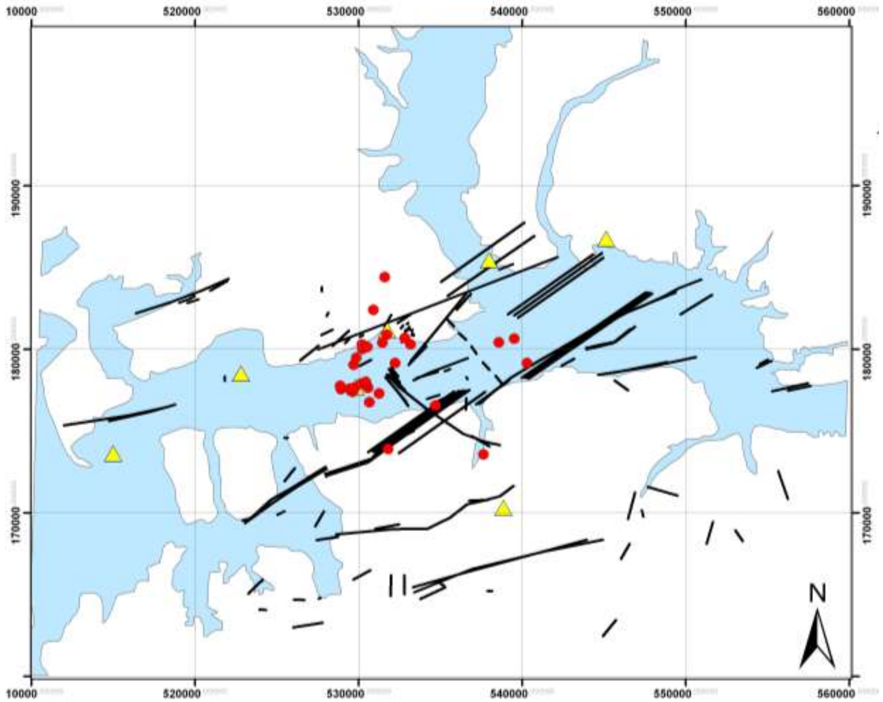
2. Extent of Kempton Park Gravels



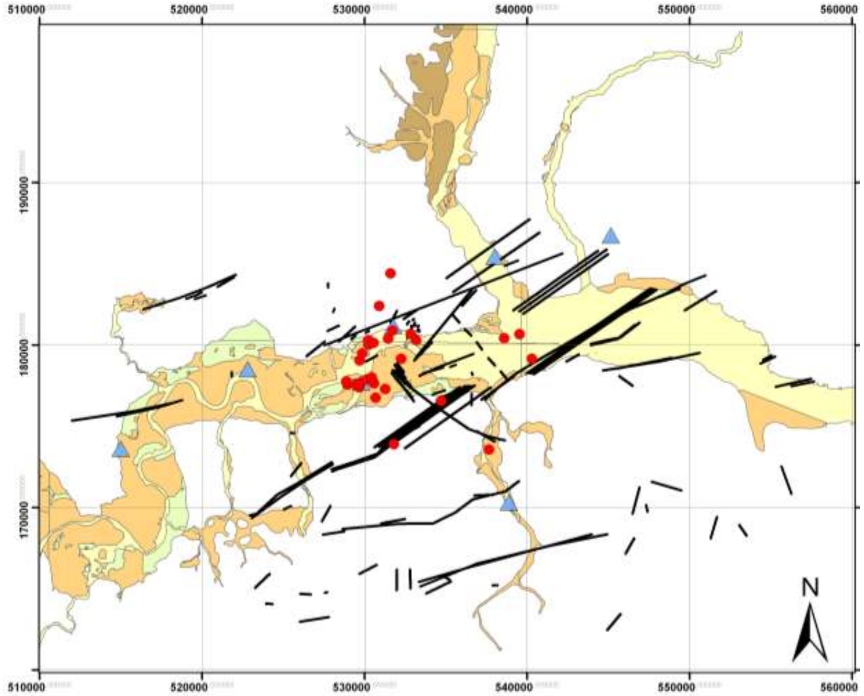
- •BGS 1:50,000 digital geological map data
- •DIGMapGB50 provides a 2D expression of superficial deposits present at ground surface
- •Gibbard (1994) has been used to help refine the sub-surface distribution
- •26 of 31 occurrences occur beneath the Kempton Park Gravel Member

Similar extent: Artesian zone and Kempton Park Gravel

Artesian zone

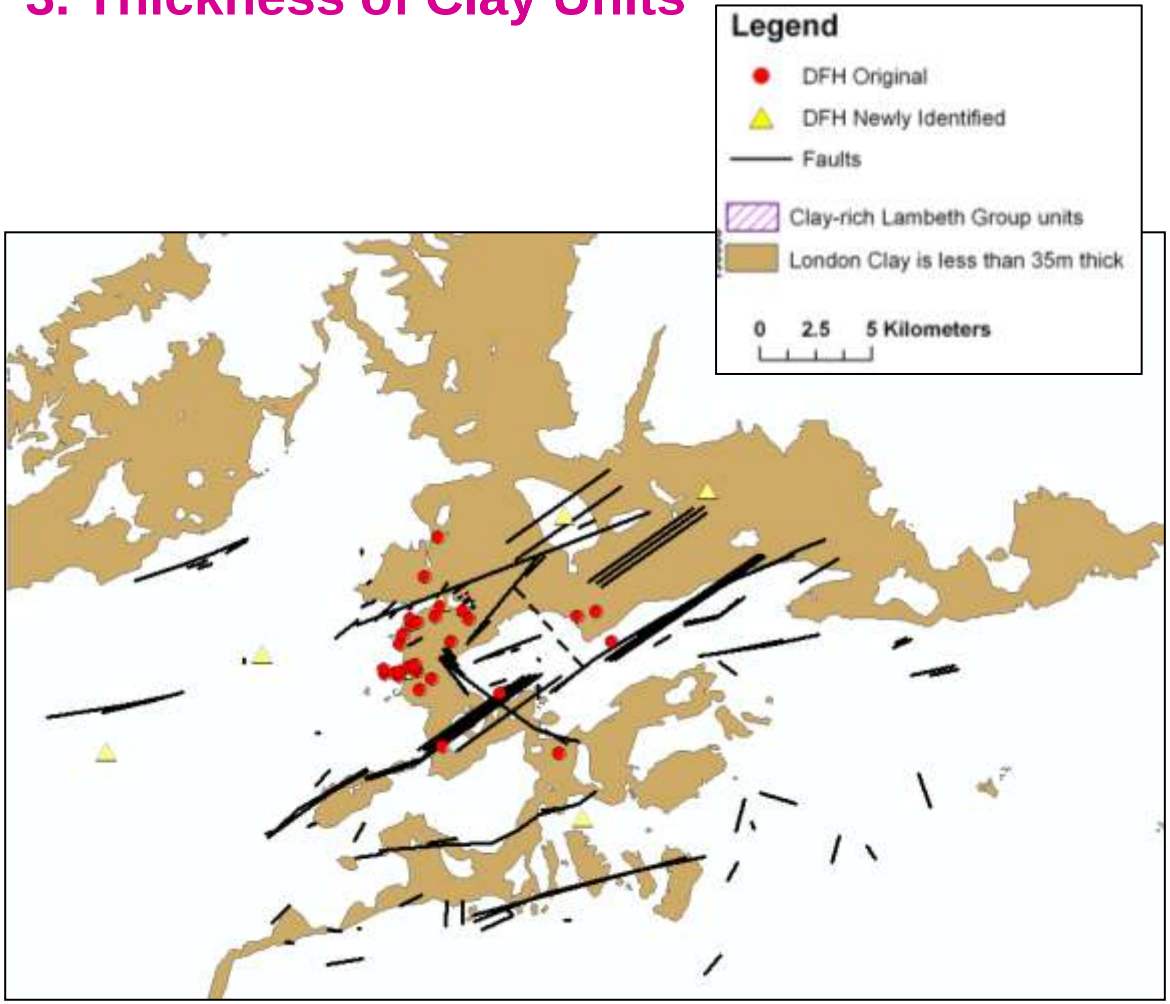


Kempton Park



Developing a Hazard Susceptibility Map

3. Thickness of Clay Units



- Provides a confining layer for artesian groundwater pressures and regulates pore pressure release. At less than 35 m restricted supply possible
- Used 3D Geological Model for London
- Thickness model for LC was imported into the GIS
- 3 of 31 occurrences where the thickness of London Clay exceeds 35 m (max 43.9 m)
- 4 DFHs occur where there is no London Clay present

Developing a Hazard Susceptibility Map

Thickness and nature of over burden on top of Chalk

- Considered London Clay as a confining layer but what about other confining units?
- Looked at overburden thickness: 25 of the 31 DFH are associated with an overburden thickness of 40-65 m

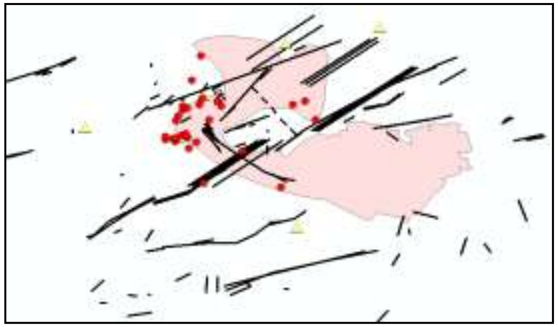
  BUT not all units will confine groundwater pressure e.g. Thanet Sands

- So looked at the units of the Lambeth Group where they are clay-rich.

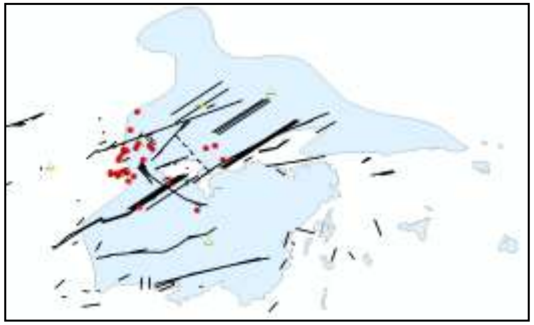
Developing a Hazard Susceptibility Map

Lambeth Group sub-divisions:

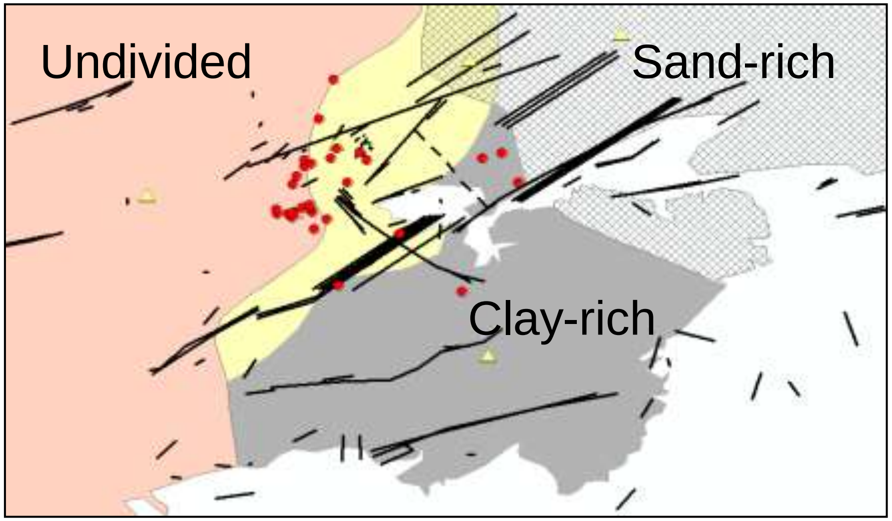
- Lambeth Group sub-divisions include in the London memoir and refined as part of another BGS project:
- Mainly interested in the East where the London Clay is <35 m or absent



Laminated beds



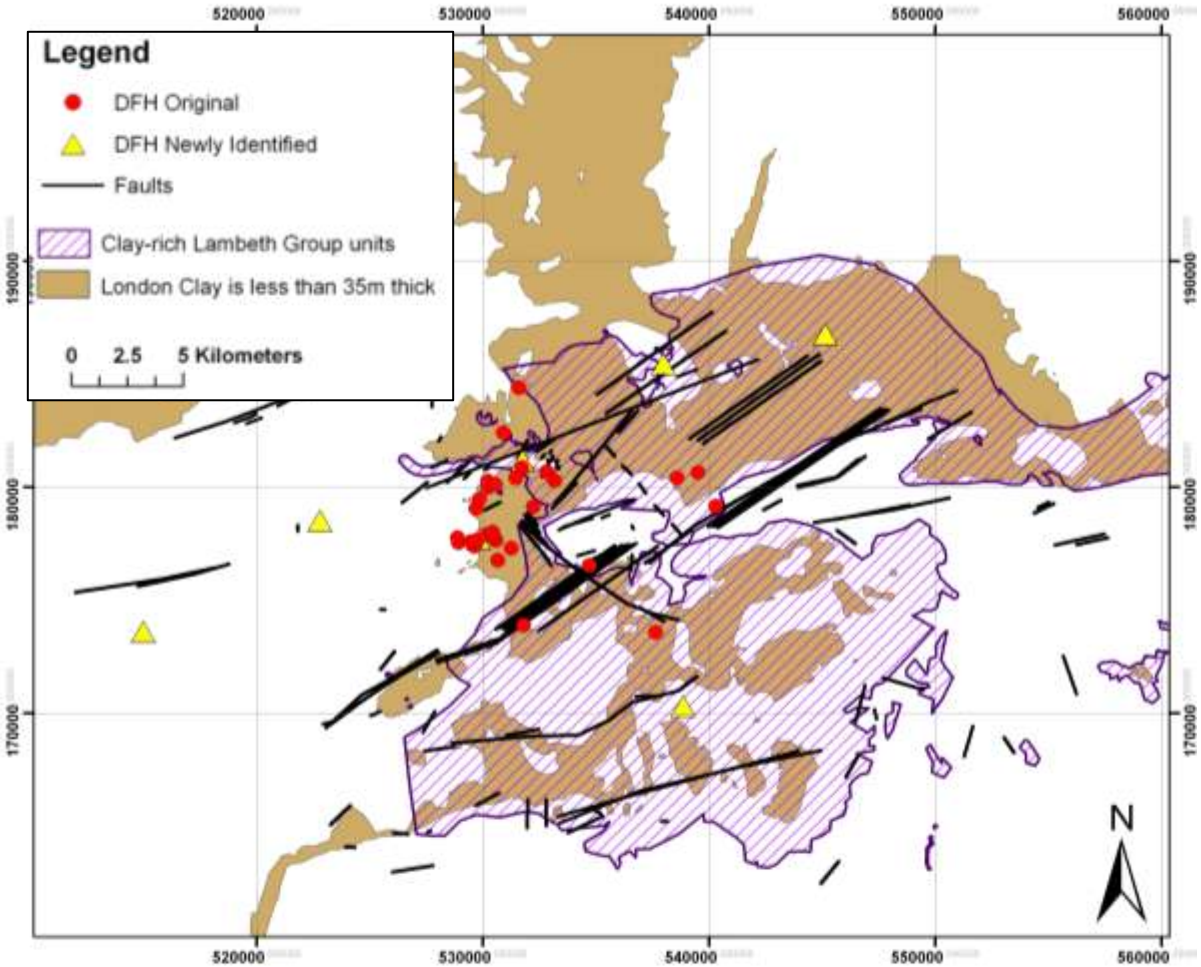
Lower Shelly Clay



Mottled beds

Developing a Hazard Susceptibility Map

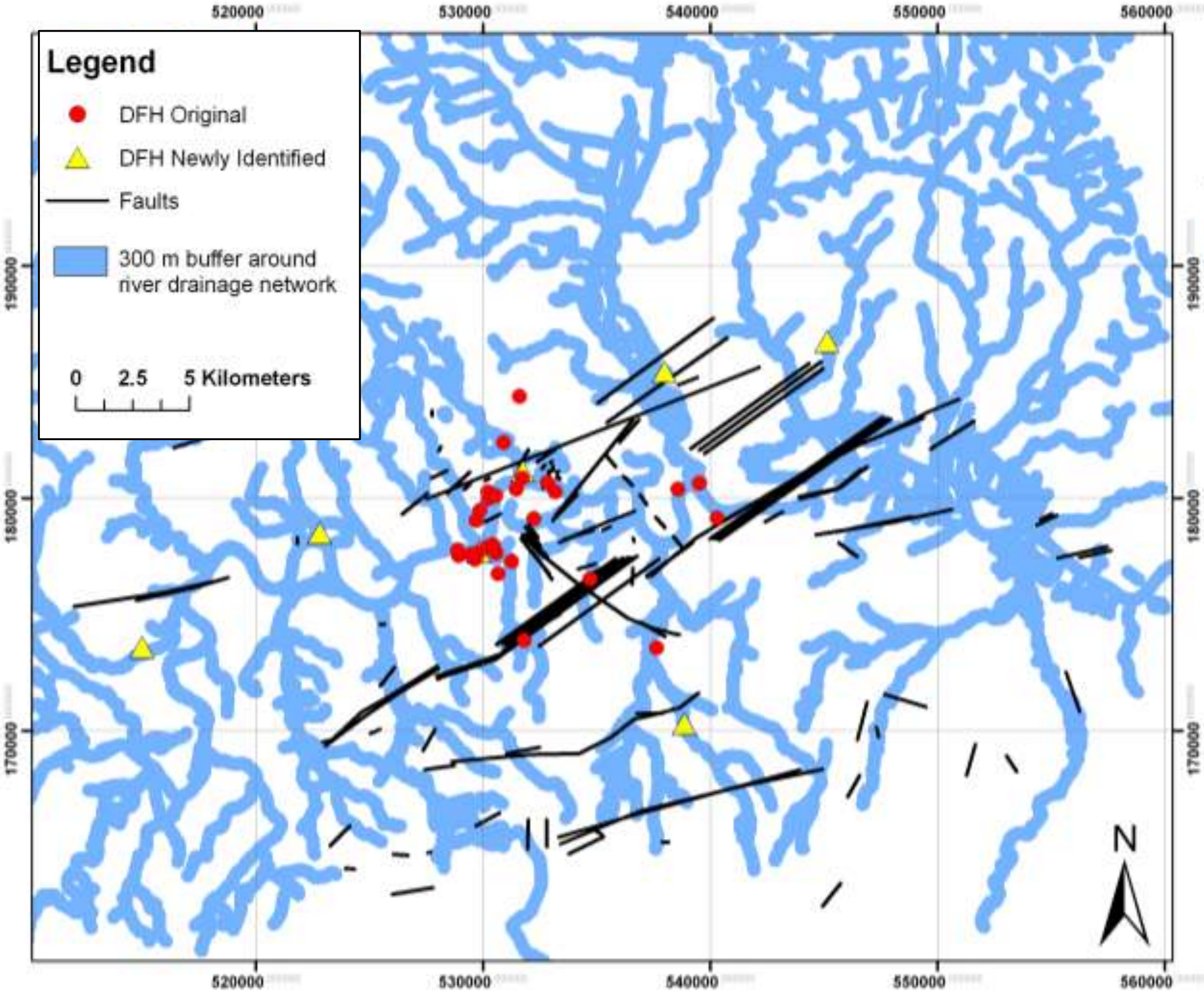
3. Thickness of Clay Units



- Combined the Lambeth Group clay-units with areas where the London Clay is <35 m thick
- Not accounted for thickness of Lambeth Group units…but unlikely to exceed 35 m
- May be areas where the thickness of the Lambeth Group units is insufficient to confined the groundwater pressure

Developing a Hazard Susceptibility Map

4. River Drainage network



- DFH are associated with valley floor locations
- River network has changed significantly since DFH formation
- Scours developed in cold-climate braided rivers
- 300 m buffer was placed around the river network to account for channel migration and morphological changes
- Are we right to include this factor?

Combining the layers to create the susceptibility map

1. Within a zone of former artesian groundwater conditions

2. Beneath the Kempton Park Gravel Member

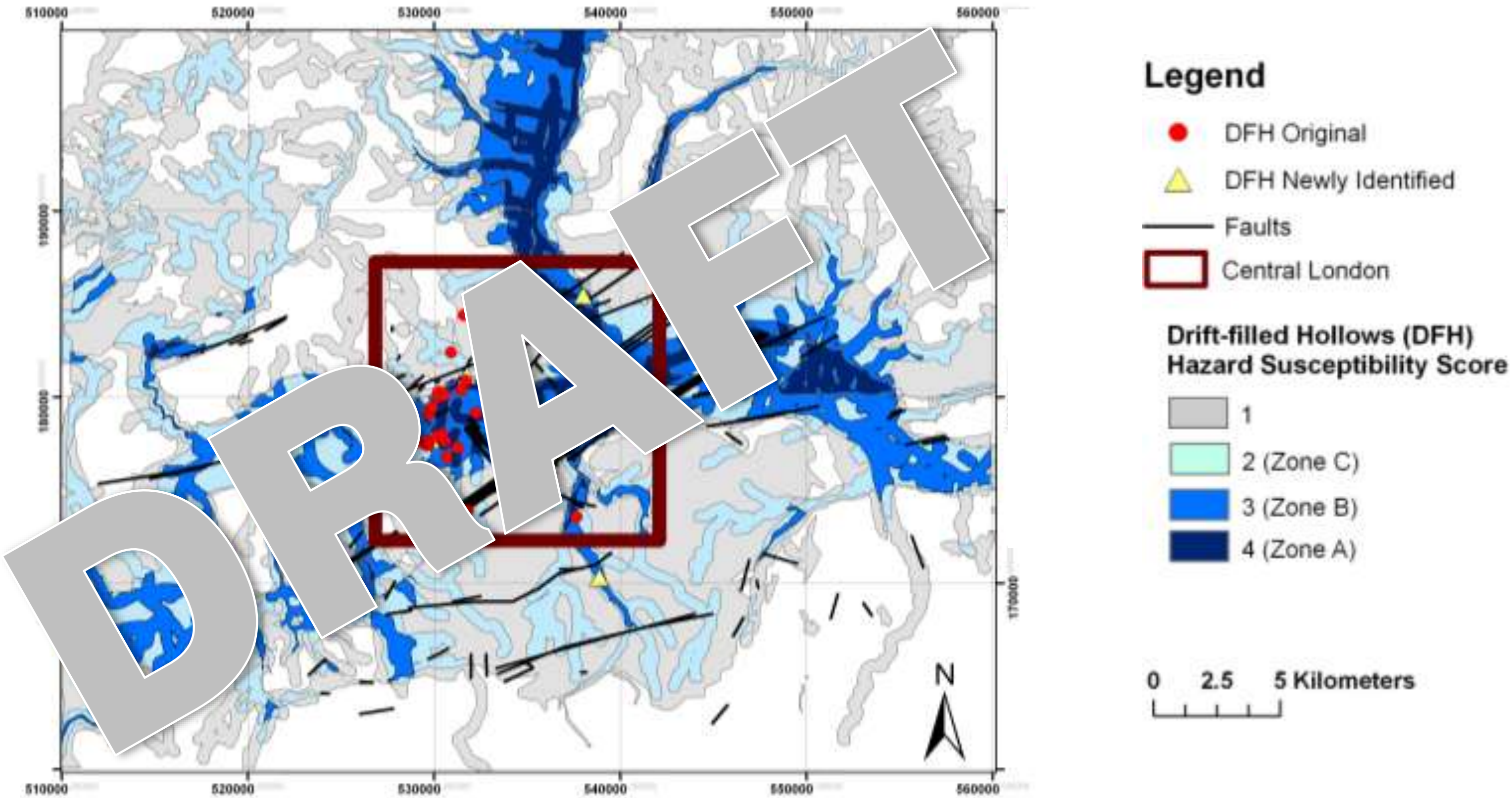
3. Where the London Clay is less than 35 m thick or where the Lambeth Group is clay-rich

4. Within 300 m of the river network

- All occurrences should occur where all the criteria are satisfied
- Interrogation of the layers showed this not always to be the case
- We therefore developed 3 zones :

A = 4 criteria
B = 3 criteria
C = 2 criteria

Hazard Susceptibility Map



How well does the map capture the location of the DFHs?

1. All occurrences should occur where all the criteria are satisfied
2. Interrogation of the layers showed this not always to be the case
3. We therefore developed 3 zones :

   A = 4 criteria
   B = 3 criteria
   C = 2 criteria

4. 81% of DFH occurred within Zones A and B

DFH originally identified

Zone	Score	No. of DFHs	% of DFHs
A	4	16	52%
B	3	9	29%
C	2	4	13%
Outside zones	<2	2	6%

Limitations with our approach

1. We haven't accounted for **different modes of formation** or for morphological features.

2. The majority of DFHs were in a small area between Battersea and Charing Cross. By definition **clustered DFHs** are likely to share the same hydro-geological setting.

BUT…Occurrence of DFH within zone A outside of the cluster suggests the criteria may be applied over the wider area

3. DFHs are only uncovered when **deep excavations** are dug for developments. Most development has occurred within Kempton Park Gravel.

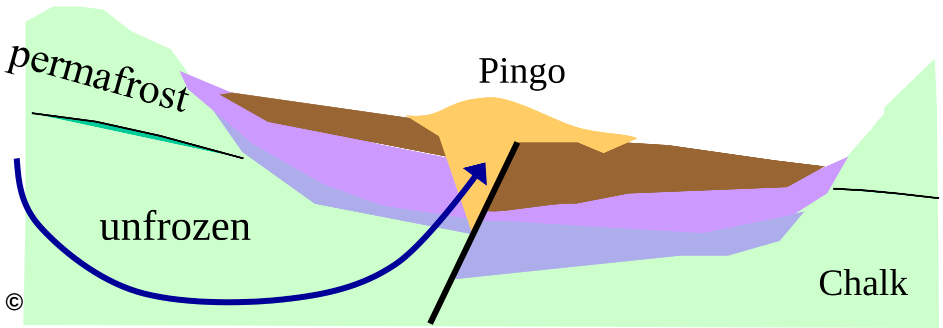
4. Quantitative assessment of **faults** has not been included.

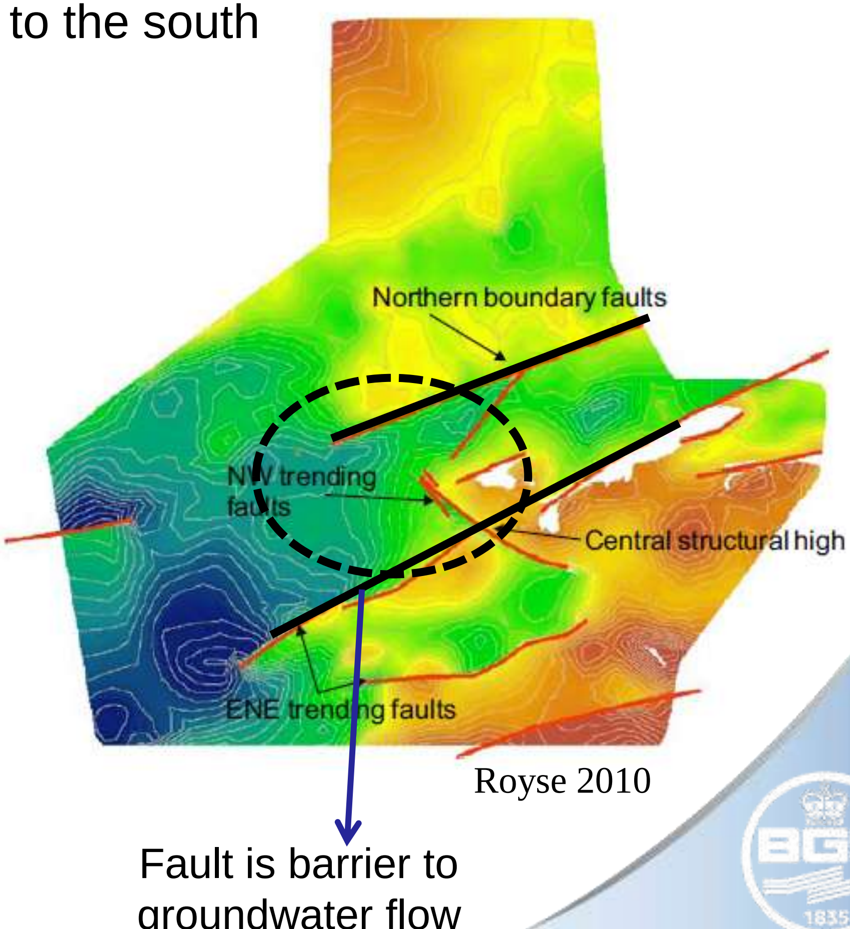
5. Potential **overlap/double accounting** with current contributory factors

6. Only covers **Central London**.

Drift Filled Hollows Association with Faults

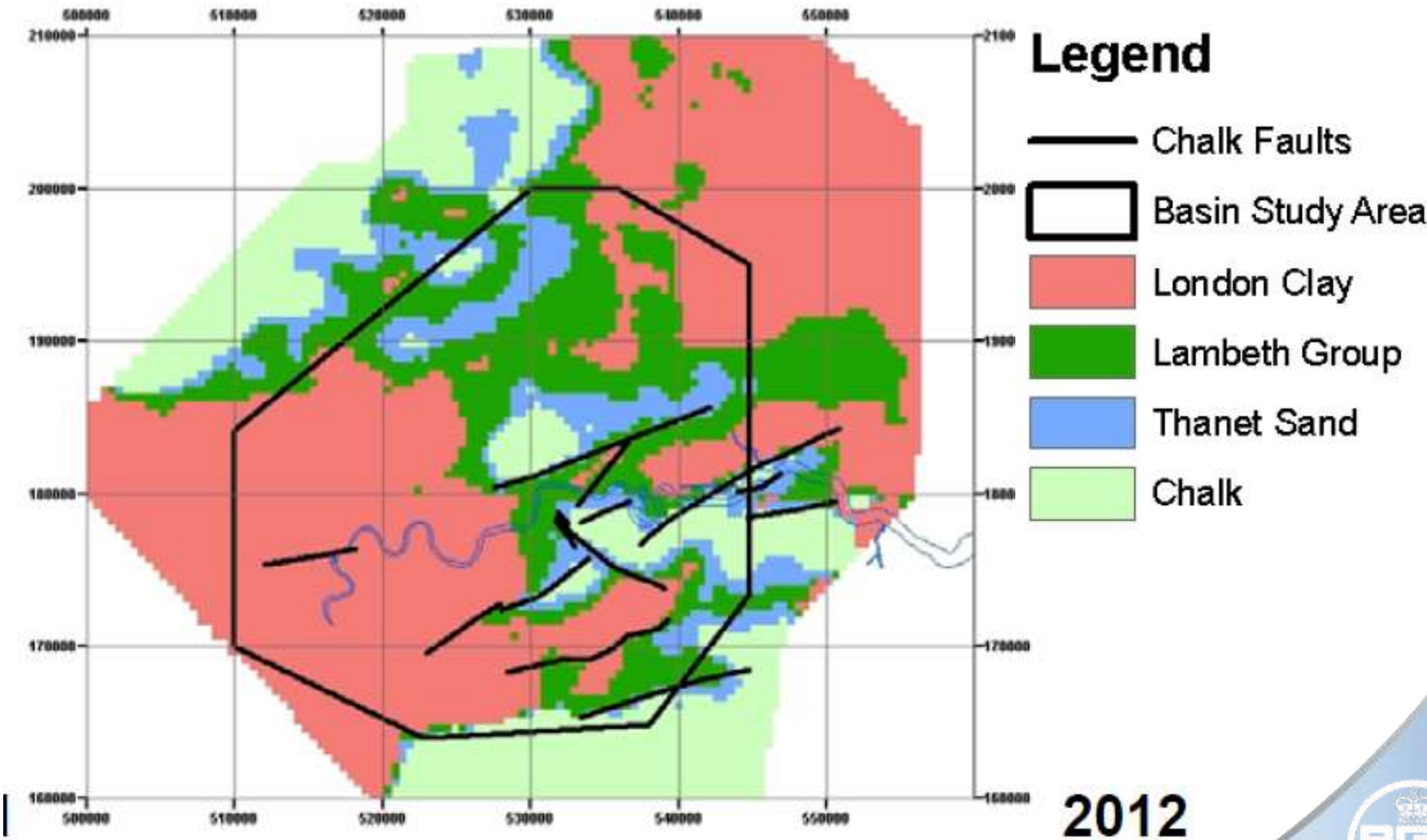
- Half of the DFHs lie within 1 km of a fault.
- The majority of the DFH fall between the Northern boundary fault to the north and the Streatham and Greenwich faults to the south
- The chalk is expected to be highly deformed with a greater propensity for fracturing and faulting.
- Potential for structural control of groundwater upwelling
- An area of preferential groundwater discharge for DFH development within this faulted zone ?





Drift Filled Hollows – Pathway to deep groundwater

Watertable Geology



Environment Agency - Management of the London Basin Chalk Aquifer, Status report 2012

Future look…

- Need to understand more about the process of formation
- Classify the DFHs based on how they were formed
- Need a better way of dealing with the associated of DFHs with valley floors and cold-climate rivers
- Closer look at the association with faults and chalk structure
- Need to think beyond central London

Summary

1. The Hazard susceptibility map for DFH will provide planners with a broader awareness of the potential location of difficult ground conditions associated with these features

2. The associations demonstrated in the GIS layer are insufficient to verify the processes associated with the formation of the *DFH*

3. Through developing the process understanding it should be possible to further refine the potential for encountering these features.

Questions ?

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