

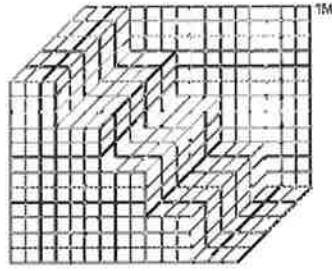
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**ANNEX B**

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**REVIEW OF ARUP  
INSTABILITY REPORT**

**BURO HAPPOLD**



Buro Happold

**Review of Arup Instability Report  
West of Twerton**

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## Contents

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<b>1</b>	<b>Introduction</b>	<b>9</b>
<b>2</b>	<b>Geology and Topography</b>	<b>10</b>
<b>3</b>	<b>Specific Observations</b>	<b>11</b>
<b>4</b>	<b>Discussion</b>	<b>13</b>
<b>5</b>	<b>Conclusions and Engineering Recommendations</b>	<b>15</b>

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## 1 Introduction

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Buro Happold Limited was appointed by the Duchy of Cornwall to review findings given by Arup in their report 'Scope, Geological Instability and Undermining Study – Bath Urban Extension Development' (Job No 2/23/6 March 2010); specifically addressing the area West of Twerton. This report addresses the conclusions drawn by Arup specifically defined within Figure 25 'Air Photo Interpretation – Twerton', which indicates approximately 50% of the land area to be unsuitable for development.

Focus is initially given to the geology and topography of the study area; this is related to the anticipated geotechnical properties of the material groups. Subsequently a discussion is provided on field observations and the appropriate use of aerial photography. The concluding sections suggest a significant reclassification of the project area. Methods to control degradation of materials and slopes are provided to identify the way in which the greater majority of the area could be utilised for future development. Recommendations for some intrusive, low cost, investigation are subsequently given to better define the likely scope of construction works that would be required for any future low rise development.

## 2 Geology and Topography

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Figure 10 'Solid Lithography' of the Arup report identifies three main geological limits to be present (exposed) within the land West of Twerton. Specifically:

- Blue Lias – Interbedded limestone and mudstones;
- Penarth Group – A mix of limestones, shales and marls;
- Mercia Mudstone Group – Red sandy and silty mudstones.

The important feature to note at this juncture is that these materials are described, in their unweathered state, as rocks; albeit the mudstones can be in a relatively weak state. By contrast the areas where landslipping has predominantly occurred, in and around Bath, are within the Fullers Earth and Lower Lias Clays.

An additional point, in relation to landslipping, that should be cited regarding engineering behaviour of clay deposits is that in conjunction with slope angle consideration should be given to plasticity. The Lower Lias and Fullers Earth clays are generally of high plasticity. By contrast Mercia Mudstone, which does weather to a clay, has low plasticity. Clays of low plasticity do not normally form extensive slip planes, but can exhibit the slumping observed within the railway cutting.

The topography of the site is tempered by the geology and the presence of the flood plain for the River Avon to the north and Newton Brook to the eastern boundary. The relatively flat core of the site is capped by the Blue Lias; the implication is that the limestone in this formation has constrained any downward degradation. Beyond the Blue Lias the site slopes to the north, east and west; because of the rocky nature of predominantly the Mercia Mudstone a relatively steep perimeter to the Blue Lias is maintained. Further from the limestone cap the slope angles reduce, affected undoubtedly by weathering of the mudstones. There is a natural steepening of the ground, caused by down-cutting of Newton Brook. The construction of the railway also necessitated cutting and steepening of the ground in its immediate vicinity.

## 3 Specific Observations

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### BGS Mapping

Arup make extensive use of the BGS mapping undertaken in the Bath area, contained within the 1985 publication entitled 'An Environmental Geology Study of parts of West Wiltshire and South East Avon' by Forster et al. Examination of three specific maps indicate the clear distinction the BGS draw between material type, slope angle and areas of unstable ground:

- Map 9c and 9d – Engineering properties of superficial deposits.
- Map 11 – Distribution of slope angle.

Map 11, as reproduced in Arup's report Figure 23, show the steeper angles of the ground that skirt the Blue Lias plateau. However maps 9c and 9d give no indication of foundered or landslipped, strata within the Twerton area under consideration; except for the Blue Lias immediately in proximity to Newton Brook, where significant down-cutting has taken place.

### Aerial Photography

Arup appear to have given great significance to minor features observed on the aerial photograph taken in June 1968; reproduced in Figure 21. It is unclear whether each of the features was then examined in their walkover survey of 19 February 2010, although the way section 2 of their report is worded, it appears not. The BGS report specifically cites aerial photography, '...an interpretation of aerial photographs is an invaluable aid to thematic geology studies..... There is, nevertheless, no substitute for 'muddy boots'...'.

It should be realised that the BGS reviewed a number of sets of aerial photographs of the area, but appear to have drawn specific conclusions only after site walkovers. To reiterate the BGS only identified one local instability feature within the Twerton zone adjacent to Newton Brook.

### Site Walkover

The author briefly visited four primary locations, where Arup identify areas of instability in their Figure 24.

- A. The railway cutting – slumping at the crest of the cut slope was observed.
- B. Wooded area, in the northeast corner of the site, below the Stoney Lane track – over the last few years the ground appears to have been regraded and planted. No obvious downslope movement was observed.
- C. Immediately to the west of Seven Acre Wood – the ground falls away relatively steeply, and is very stoney (mudstone/limestone blocks).
- D. Eastern edge of the site, circled on the Arup drawing – as with B, this area has been planted with trees. There is some uneven grassed areas above the planted area.



Unfortunately, due to the agricultural use of the greater majority of the area any minor natural features and ground movement are potentially masked.

## 4 Discussion

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In contrast to the vast majority of the Bath area the site west of Twerton is underlain by relatively stable geological strata. It is considered inappropriate to relate potential development primarily to slope angle when the inherent geotechnical properties of these strata are at significant variance with the clays that cover much of the rest of the city and its surroundings. BGS have clearly drawn a similar conclusion, by comparison of Maps 9 and 11 of their report, as the regions of high slope angle on the site are not considered landslipped or unstable.

The features that Arup do however raise, which are of importance, are surface and ground water. With sloping ground it can be expected that significant surface flow can develop, during periods of intense or prolonged rainfall, as the surface deposits are relatively impermeable. This will lead to degradation of the steeper, and unvegetated, slopes; observed adjacent to the railway and Newton Brook.

Arup also indicate the presence of limestone bands, in the Blue Lias and Penarth Group, can lead to groundwater springs where limestone daylight in the hill slopes, ie below Seven Acre Wood. Again the free flow of water over the ground surface can precipitate degradation and consequent slumping of the mudstone/clay type deposits of the Mercia Mudstone Group.

## 5 Conclusions and Engineering Recommendations

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This reassessment of the site west of Twerton has shown that most of the area is suitable for development. The conditions that do limit the extent of any development work are:

- Steeply sloping ground in the vicinity of Newton Brook;
- The railway cutting.

Although not discussed in this report the archaeological interest of the Roman remains to the south of the site may require particular conditions to be applied to any works in this area. There is also evidence of Made Ground, of unknown provenance, to the north of the railway, which may need improvement prior to construction.

As the ground does have significant slopes to the north, west and east of the site, cut and fill to form terraces may prove beneficial for any development. The upper metre of the Mercia Mudstone may be too weathered, and consequently too wet, for subsequent use as engineered fill.

To form relatively steep cuts in the mudstones it would be advisable to protect the faces using geofabrics, potentially nailed and seeded to allow growth of vegetation. At the top, and/or base, of these cuts drains should be installed to control water on the face of the cuts, prevent uncontrolled water flow across the site, and prevent ponding on any man made terraces. Where cuts expose limestone bands at the surface, it would be advisable to follow recommendations for cuts in mudstone, but with the addition of a geotextile drainage layer adjacent to the face. The water can then be collected at the base of the cut, and removed along predetermined/constructed drainage channels.

For foundations, for low rise housing developments, it is anticipated much of the work will consist of pads or strips placed on limestone or mudstone horizons. Locally trench fill may be necessary in areas of terraces formed by compacted soils, or where mudstone has weathered to several metres depth.

### **Recommendations for Further Work**

To prove the general conclusions drawn in this report it would be advisable to undertake a trial pitting exercise across the site. The purpose of this would be:

- To examine the structure and weathering, and consequently the strength, of the various geological limits;
- Allow a clearer picture to be obtained of possible water flow within limestone layers, particularly in the Penarth Group;
- Obtain index properties, particularly of any weathered deposits, to prove any potential for future slope instability;
- Examine the composition of known areas of Made Ground.



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