St. Athan Northern Access Road (NAR) - Ground Investigation Report

Welsh Government

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		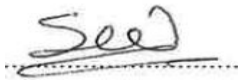	
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Executive Summary

AECOM Limited has been appointed by the Welsh Government to design a new access road to serve the Aerospace Business Park in St. Athan. The new road, which is referred to as the Northern Access Road, will provide a link from the B4265 near Llantwit Major in the west to Eglwys Brewis Road in Picketston in the east.

This Ground Investigation Report provides details of a ground investigation undertaken by AECOM in December 2016 and has been prepared in accordance with the Design Manual for Roads and Bridges (DMRB) Section 4.1.2, HD 22/08, 'Managing Geotechnical Risk' (Ref. 1) in order to support the detailed design and construction of the St. Athan Northern Access Road.

The following provides a summary of the key findings:

Site Description The scheme includes the provision of a 2.0km highway link (single two lane carriageway) with associated drainage features, to the Aerospace Business Park. The alignment comprises the crossing of a small number of watercourses (Llanmaes Brook and Boverton Brook) with associated approach earthworks including embankments and cuttings up to 5m in depth /height. Other significant features along the scheme include two culverts and four junctions with the existing road network at Eglwys Brewis Road.

Site Environs The scheme area is located in St. Athan, South Wales approximately 6.3 km west of Cardiff airport. It is accessed from the B4265 via Eglwys Brewis Road. The landscape is predominantly agricultural with the Llanmaes Brook running north to south through the scheme. Boverton Brook and Nant y Stepsau run along the northern and southern boundary of the proposed road respectively. The topography of the Scheme area generally falls towards Llanmaes Brook (Ch. 0 to Ch. 600) after which it is generally flat across the proposed alignment.

Site Reconnaissance The site walkover indicates the site comprises the following areas (from west to east within site boundary):

- B4265 located west of the site (Ch.0)
- Llanmaes Brook is in the western extent of the site and passes through a horse riding school. The brook will cross the proposed alignment between Ch. 400 – 420m. At the time of survey the water level in Llanmaes Brook was relatively high which was anticipated due to heavy rainfall on the day. The water was clean and the stream bed was visible.
- Boverton Brook runs south of the alignment from Ch. 0 – Ch.1570 where it also crosses the proposed alignment Ch. 1520 – Ch1570m.
- Millands Caravan Park is located approximately 30m north of the proposed road (Ch. 900m).

During the initial site walkover the Fire Training area and Nant y Stepsau brook were not observed due to hedgerows along Eglwys Brewis Road and locked access gates belonging to the St. Athan MoD site.

Ground Conditions The exploratory holes encountered Made Ground and Topsoil overlying Alluvium and the Porthkerry Member. The investigation highlighted the presence of a thin covering of Alluvium across the site which was not suggested by the published geological records.

Groundwater There is shallow groundwater on site. Groundwater was encountered from 0.7m bgl to 0.8m bgl. The groundwater level within the Alluvium is between 40.5m AOD and 41.3m AOD. The groundwater table within the Porthkerry Member is situated between 40.6m AOD and 42.9m AOD.

Soakaways The ground conditions do not appear suitable for the use of pit soakaways.

Limitations

The opinions expressed in this report and the recommendations given, are based on the information obtained from the desk assessment and on the ground conditions encountered during the site work and on the results of tests made in the field and in the laboratory, together with AECOM's conjectural interpretation between exploratory holes. The information, views and conclusions drawn concerning the site are based, in part, on information supplied to AECOM by other parties. AECOM has proceeded in good faith on the assumption that this information is accurate. AECOM accepts no liability for any inaccurate conclusions, assumptions or actions taken resulting from any inaccurate information supplied to AECOM from others.

The comments made on groundwater conditions are based on observations made during site work and the limited monitoring programme. It should be noted that groundwater levels might vary owing to seasonal or other effects.

As the material encountered and samples obtained during the on-site investigations represent only a small proportion of the materials present on-site, there may be other conditions prevailing at the site which have not been revealed by this investigation and which have therefore not been taken into account in this report. Where suspect materials are encountered during future site works, additional specialist advice should be sought to assess whether the new information will materially affect the recommendations currently given and whether further measures are needed.

Table of Contents

Figures

1. Introduction

AECOM Ltd. (hereafter referred to as “AECOM”) has been appointed by the Welsh Government to design a new access road to serve the Aerospace Business Park in St. Athan. The new road, which is referred to as the Northern Access Road (NAR), will provide a link from the B4265 near Llantwit Major in the west to Eglwys Brewis Road in Picketston in the east.

In order to support the detailed design and construction of the new road, AECOM has been commissioned to undertake a geotechnical assessment in respect of the proposed NAR, hereafter referred to as ‘the site’.

As part of this appointment, a ground investigation has been undertaken to obtain information on the geotechnical ground conditions and to assess potential constraints to the proposed development. The current investigation was completed in December 2016. This report summarizes the findings of the investigation highlighting the geotechnical risks to the proposed development.

1.1 Scope and Objective of the Report

The scope consists of the following:

- The undertaking of a Ground Investigation at the site in accordance with the Design Manual for Roads and Bridges Section 4.1.2, HD22/08, ‘Managing Geotechnical Risk’ (Ref. 1);
- A presentation of all available geotechnical information including geological features and relevant data;

This report presents a factual description of the fieldworks and laboratory testing results, and derives characteristic geotechnical design parameters. This report fulfils the requirements of a Ground Investigation Report (GIR), prepared in accordance with HD 22/08.

1.2 Description of the Project

The Scheme includes the provision of a new road to connect the Aerospace Business Park running from the B4265 near Llantwit Major in the west to Eglwys Brewis Road in Picketston in the east. The new road will comprise an all-purpose road approximately 2.0 km in length. A site location plan is presented in Figure 1. The current scheme proposals are shown on AECOM Drawings 60509148-SHT-30-0000-CT–0601 to 0604 (Appendix A).

1.3 Geotechnical Category of Project

The St. Athan Northern Access Road is considered to be a Category 2 project, as stipulated in HD 22/08. The Project is considered a conventional road development, involving standard earthworks procedures, in generally consistent ground conditions with no exceptional geotechnical risks. Quantitative geotechnical data (field and laboratory testing), derived from previous sources of information and site specific intrusive investigation, forms the context for geotechnical design.

2. Existing Information

2.1 General

The following section provides a summary of information reported previously in the Preliminary Sources Study Report (PSSR) (Ref.2).

2.2 Topographical Maps and Aerial Photographs

The topography of the Scheme area generally falls towards Llanmaes Brook (Ch. 0 to Ch. 600) after which it is generally flat across the proposed alignment.

At Ch.0m (B4265) the ground level falls from 44.7m AOD to 35.47 at Llanmaes Brook. The relief then rises from 35.47m AOD to 42.97m AOD at Ch. 600 after which the relief generally remains constant (circa 42.0m AOD).

2.3 Geological Maps and Existing Ground Investigation Data

The geological maps, together with the BGS borehole logs indicate that the geology beneath the site consists of the Jurassic Porthkerry Member (Blue Lias Formation); comprising interbedded limestone and calcareous mudstone or siltstone. During the site walkover the tenant farmer for Millands Farm (Plot 14) indicated that the land was built up in plots 14 and 16 (Millands Farm and Tremains Farm) and as such Made Ground is anticipated in these areas towards the western end of the site near Llanmaes Brook.

Drift Deposits

The published 1:50,000 scale geological map (Sheet 262 “Bridgend”, 1990) indicates there are no superficial deposits on the site. There are localised deposits of alluvium within 60m of the site which were predominantly mapped along Boverton Brook.

Solid Geology

Porthkerry Member (Blue Lias Formation)

The underlying Porthkerry Member can be in excess of 140m thick and comprises limestone, calcareous mudstone and siltstone. Individual limestone beds are usually between 0.1 – 0.3m thick.

2.4 Records of Mines and Mineral Deposits

There are two records of mining or quarrying within 100m of the site boundary. The Parwg (40m SE) and Great Farm (68m E) opencast quarries were registered limestone quarries (operations have ceased). The historical OS maps have also identified quarries in the vicinity of the site. Further details are listed in Table 4.2 of the PSSR (Ref.2).

2.5 Land Use and Soil Survey

The 1:100,000 scale Soil Survey of England and Wales (Sheet No. 36 Mid Glamorgan) (Ref.5), indicates that the soils in the study area are of intermediate to high leaching potential which either has the potential to “transmit a wide range of pollutants (intermediate leaching potential) or readily transmit non-absorbed pollutants and liquid discharges but which have some ability to attenuate absorbed pollutants and liquid discharges but which have some ability to attenuate absorbed pollutants (high leaching potential)’.

2.6 Archaeological and Historical Investigations

A number of archaeological investigations have been undertaken at the site. The buried remains of an archaeologically significant wall were identified along the western extent of the road (SK501) during the recent ground investigation. Further reference should be made to AECOM’s Historic Environment Desk Based Assessment (Ref. 19).

2.7 Existing Ground Investigations

A number of ground investigations have been previously undertaken at the St. Athan site. The most relevant investigations are detailed in this discussion. The Factual Reports are enclosed in Appendix B.

2.7.1 Soil Mechanics Investigation

A ground investigation (Phase 1) was carried out in November 2009, undertaken by Soil Mechanics under the instruction of Capita Symonds (CS), comprising of machine excavated trial pits, hand dug trial pits, rotary drilled boreholes, handheld windowless sample boreholes, soakaway infiltration tests, in-situ testing/monitoring and a suite of geotechnical laboratory testing. An overview of the ground investigation is presented in Table 2.1.

Table 2.1 Summary of Ground Investigation – November 2009 (Soil Mechanics)

Exploratory Hole Type	Exploratory Hole ID	Quantity	Maximum Depth (m bgl)
Boreholes (Rotary Core)	BH450 and BH455	2	15
Handheld Windowless Sample	WS01, WS01 and WS02	3	0.65
Trial Pit (machine excavated)	TP-RP1, TP-402 SA, TP-403 to TP-414, TT-411	14	3.15
Trial Pit (hand dug)	TP-EB1 to TP-EB8	8	1.3

2.7.1.1 Made Ground

Made Ground was encountered in most exploratory holes across the scheme. The Made Ground encountered was predominantly associated with the excavation of the exploratory holes within and in the vicinity of the existing road (Elgwys Brewis Road). The material was generally as either tarmcadam (wearing course) or as soft to firm light grey to brown silty sandy fine to coarse gravel of limestone with medium cobble content. Cobbles are limestone (probable sub-base).

2.7.1.2 Porthkerry Member (Blue Lias Formation)

The Porthkerry Member was encountered in most exploratory holes across the site. The Porthkerry Member typically comprised strong to very strong light grey limestone. Locally there is light brown staining penetrating up to 2mm and a slight loss of strength along fracture surfaces. Discontinuities are sub-horizontal closely and medium spaced planar and undulating locally with clay infill <2mm. A weathered zone is present which is generally described as firm dark brown slightly sandy gravelly silty clay with low cobble content. Gravel is fine to coarse limestone and cobbles are limestone. The top of the Porthkerry Member was encountered between ground level and 0.55m bgl. Generally, in areas where Made Ground was absent it was encountered at ground level.

Four (4 No.) Atterberg Limit Tests were undertaken on four samples collected from the weathered section of the Porthkerry Member between 0.2m bgl and 0.7m bgl. The plastic and liquid limits ranged from 27% to 44% and 51% to 98% respectively. The plasticity index ranged from 14% to 54%. These results classify the clay to be of high plasticity.

2.7.1.3 Groundwater

Three groundwater strikes were recorded during the investigation. One strike was encountered at 0.5m bgl in the Made Ground. The other two groundwater strikes were recorded within the weathered Porthkerry Member at 0.72m bgl and 0.8m bgl.

2.7.1.4 Environmental

Environmental samples were taken during the investigation but the results were not listed in the report.

2.7.2 Apex Drilling Investigation

A ground investigation was carried out from January to February 2003, undertaken by Apex Drilling and Enviros, comprising of machine excavated trial pits, rotary drilled boreholes and in-situ CBR tests and testing/monitoring. A suite of geotechnical laboratory testing was also performed. An overview of the ground investigation is presented in Table 2.2.

Table 2.2 Summary of Ground Investigation – January-February 2003 (Apex Drilling and Enviros)

Exploratory Hole Type	Exploratory Hole ID	Quantity	Maximum Depth (m bgl)
Boreholes (Rotary air flush)	BH1-BH5, BH9 – BH10, BH17 – BH24	14	12
Trial Pit (CGC) (machine excavated)	CGCTP1 – CGCTP12	12	1.9
Trial Pit (machine excavated)	TP1 – TP14, TP17 – TP20, TP27 – TP46	36	2.2
CBR	CBR1 – CBR16	16	0.75

2.7.2.1 Made Ground

Made Ground was encountered in two exploratory holes north of the proposed alignment. The material was generally described as firm dark brown clay with gravel and cobbles of limestone. Occasional fragments of blue plastic sheeting, brick and concrete were reported.

2.7.2.2 Porthkerry Member (Blue Lias Formation)

The Porthkerry Member was encountered in most exploratory holes across the site. The Porthkerry Member typically comprised very weak to strong dark grey thinly to medium bedded crystalline limestone with many large pockets of soft orange brown silty clay. A weathered zone is present which is generally described as firm orange brown very silty clay with low cobble content. Gravel is fine to coarse limestone and cobbles are limestone. Generally, the top of the Porthkerry Member was encountered at ground level. In the areas where Made Ground was present it was encountered between 0.45m and 0.6m bgl.

Atterberg Limit tests were undertaken on five samples collected from the weathered section of the Porthkerry Member between 0.2m bgl and 0.7m bgl. The plastic and liquid limits ranged from 20% to 40% and 50% to 66% respectively. The plasticity index ranged from 26% to 30%. These results classify the clay to be of high plasticity.

Sixteen (16 No.) CBR tests were performed in the laboratory within the Porthkerry Member. The results ranged from 0.9% to 2.1% (avg. 1.4%).

2.7.2.3 Groundwater

No groundwater information was recorded on the exploratory hole logs.

2.7.2.4 Environmental

Environmental samples were taken during the investigation but the results were not listed in the report.

2.7.3 Pell Frischmann Investigation

A ground investigation was carried out from August to October 2009, undertaken by Soil Mechanics, comprising of machine excavated trial pits, windowless sample boreholes and rotary drilled boreholes including testing/monitoring. An overview of the ground investigation is presented in Table 2.3. The St. Athan NAR road lies with the Picketston and East Camp areas in the report.

Table 2.3 Summary of Ground Investigation: August – October 2009

Exploratory Hole Type	Quantity
Boreholes (Rotary)	17
Trial Pit (machine excavated)	169
Windowless sample boreholes	21

2.7.3.1 Made Ground

Made Ground was encountered during the investigation. It was generally thin and associated with the St. Athan MOD site.

2.7.3.2 Porthkerry Member (Blue Lias Formation)

The Porthkerrry Member was generally encountered between 0.4 and 2m bgl. It comprised a weathered section described as sandy gravelly clay with gravel and bedrock. The bedrock was described as horizontally bedded strong to very strong light grey limestone with occasional fossil fragments. The rock is intermittently to regularly interbedded with a weak to medium strong dark grey siltstone or shale, as layers up to 0.35m thick.

2.7.3.3 Groundwater

The groundwater monitoring results obtained during the ground investigation indicated groundwater depths in the range of 0.32m bgl to 3.32m bgl (41.42m AOD and 42.59m AOD) in Picketston and 3.2m bgl and 9.98m bgl in the East Camp site. The shallowest groundwater results were encountered in the areas of lowest relief along Boverton Brook and Eglwys-Brewis Road.

The results of the geo-environmental tests recorded exceedances of Total Petroleum Hydrocarbons (TPH), Polycyclic Aromatic Hydrocarbons (PAH) and Perfluorooctane Sulphonate (PFOs) within the Made Ground. No contaminant exceedances were recorded within the natural strata.

2.7.4 WYG Investigation

A ground investigation was carried out between 8th and 13th October 2010, undertaken by White Young Green, comprising of machine excavated trial pits, rotary drilled boreholes, soakaway tests, in situ CBR tests and laboratory geotechnical and environmental testing/monitoring. An overview of the ground investigation is presented in Table 2.4.

Table 2.4 Summary of Ground Investigation – October 2010

Exploratory Hole Type	Quantity	Depth (m bgl)
Window sample/rotary boreholes	4	4.0 – 5.5
Trial Pit (machine excavated)	15	0.42 – 1.8
Trial Pit (soakaway)	2	-

2.7.4.1 Topsoil

Topsoil was encountered during the investigation. It generally comprised of firm to stiff clay and ranged in thickness from 0.1m to 0.25m.

2.7.4.2 Porthkerry Member (Blue Lias Formation)

The Porthkerrry Member was generally encountered from ground level to 0.25m bgl. It comprised a weathered cohesive section described as sandy gravelly clay with occasional cobbles of limestone. The bedrock was described as strong grey slightly weathered limestone with closely spaced horizontal to vertical fractures with silt or clay infill.

2.7.4.3 Groundwater

The groundwater monitoring results indicated groundwater depths in the range of 1.1 to 2.0m bgl. It was concluded that the groundwater strikes were encountered at the interface between the weathered section and the bedrock within the Porthkerry Member.

2.7.4.4 Geotechnical Tests

A number of geotechnical tests were performed as part of the investigation. The results are summarised in Table 2.5.

Table 2.5 Summary of Geotechnical Test Results – October 2010

Test	Number of Results	Range (min – max)	Average
Natural Moisture Content	7	18 - 36	30
Liquid Limit (LL)	7	42 - 64	53
Plastic Limit (PL)	7	17 – 38	30
Plasticity Index (PI)	7	20 – 27	23
Modified Plasticity Index	7	19 – 25	21
Undrained Shear Strength (hand shear vane)	24	60 - >120	98
CBR (In-situ: Mexe Cone)	23	1 - 14	5.5
CBR (laboratory derived)	2	1.8 – 4.4	3.1

2.8 Consultation with Statutory Bodies and Agencies

To date there has been no consultation with statutory bodies or agencies. It is intended that this report shall support a planning application for the NAR at which stage a statutory consultation will be undertaken.

2.9 Flood Records

The Envirocheck report (Appendix C) indicates that there are localised high risk areas of flooding from rivers and seas (Zone 3) along the scheme associated with the watercourses that either cross or are in the vicinity of the scheme namely Llanmaes Brook, Boverton Brook and Nant y Stepsau. The Environment Agency categorises Flood Zone 3 as “an area that could be affected by flooding, either from rivers or the sea, if there were no flood defences.” The area is anticipated to have a 0.5 per cent (1 in 200) or greater chance of flooding by the sea each year or a 1 per cent (1 in 100) or greater chance of flooding from a river each year.

2.10 Contaminated Land

Information from the site walkover reconnaissance and PSSR (Ref.2) identified the following potential sources of contamination that may impact the proposed scheme.

Potential on site sources of contamination include:

- Made Ground – possibly present and containing contaminants including asbestos;
- Roads – fuel leakage from vehicles and run off; and
- Unexploded ordnance – there is potential for ordnance to be present due to the proximity to a military facility.

Potential off site sources of contamination include:

- Made Ground – present off site as a feature of historical stages of redevelopment of the MOD site;
- Fire Training Area – present directly north of the site at Ch. 1900m;
- Fuel Tanks – unknown contents related to the historical air field to the north of the route at approx. Ch.2000m;
- Unexploded ordnance – potential for ordnance to be present due to the proximity to a military facility; and
- Radioactive material – radium has been previously identified in the Picketston area north of the site.

MOD St Athan is located both south and north of the site. Previous environmental investigations carried out across the MOD St Athan site by Enviros Aspinwall, Parsons Brinkerhoff (PB) and WS Atkins between 2002 and 2009, as detailed by Entec 2009 (Ref. 6) identified localised contamination of metals, sulphates and petroleum hydrocarbons in soils across both West Camp (area extends from c. 100m - >1000m south of the site Ch.1600m) and East Camp (area adjacent to site extending approximately 1km south east of site Ch. 2700m).

Radiological contamination from the remnants of radium paint had been discovered in the Picketston area (area adjacent to the site's northern boundary) which has been removed in accordance with National Resources Wales (NRW) criteria in 2004. Locally elevated concentrations of metals, petroleum hydrocarbons and sulphate were also identified across the area.

In addition, Made Ground is anticipated on site associated with pre-existing roads (Eglwys Brewis Road and connecting roads) and as a feature of historical stages of redevelopment at the site and could potentially contain asbestos. Made Ground also has the potential for natural/landfill gases and other mobile contaminants and may also present an aggressive chemical environment to concrete structures.

Further reference should be made to AECOM's Phase I Geo-environmental Assessment (Ref. 20).

The Envirocheck report detailing the on-site and off-site potentially contaminative sources is provided as Appendix C.

2.11 Other Relevant Information

2.11.1 Hydrology

The site is mainly located in agricultural land and there are two brooks (Llanmaes Brook and Boverton Brook) which intersect the site perpendicular to the alignment of the proposed road. Nant y Stepsau is located at the eastern extent of the site. The key hydrological features crossing or near the site are listed below:

- Llanmaes Brook flows south, crossing the site between Ch. 400 to Ch. 420m.
- Boverton Brook is generally located south of the alignment between Ch. 0 to Ch. 1570m. The proposed highway alignment crosses the brook in the vicinity of Ch. 1520 to Ch. 1570m.
- Nant y Stepsau flows along the northern and southern boundary of the alignment between Ch. 2175 to Ch. 2350.

3. Field and Laboratory Studies

3.1 General

This section mainly describes the scope of the recent ground investigation undertaken by AECOM, the fieldwork for which was completed between 21st November and 2nd December 2016.

3.2 Walkover Survey

A geotechnical site walkover of the route alignment was undertaken by AECOM on the 28th July 2016. The walkover was undertaken over plots 6 (Great House Farm), 9 (Great House Farm), 14 (Millands Farm) and 16 (Tremains Farm). The tenant farmers for the other plots (12 Froglands Farm, 17 Boverton Court Farm and Rose Cottage) could not be contacted and as such a walkover was not possible over these areas at that time. Walkovers have since been completed across the entire site.

The purpose of the site walkover survey was to assess the condition of the site, observe any geotechnical important features and to identify any potential sources of contamination.

Generally, the site is predominantly located within an agricultural context. Due to the presence of horses, cattle and arable crops and the inability to contact some landowners, the majority of the site visit was conducted by observing the site from viewpoints along the Elgwys Brewis Road and unnamed farm roads.

From west to east the site comprises the following areas:

- B4265 located west of the site (Ch.0)
- Llanmaes Brook is in the western extent of the site and passes through the riding school where there were horses in the fields. It will cross the proposed alignment between Ch. 400 – 420m. At the time of survey the water level in Llanmaes Brook was relatively high which was anticipated due to heavy rainfall on the day. The water was clean and the stream bed was visible.
- Millands Caravan Park is located approximately 30m north of the proposed road (Ch. 900m).
- Boverton Brook runs south of the alignment from Ch. 0 – Ch.1570 where it also crosses the proposed alignment Ch. 1520 – Ch1570m.

During the initial site walkover the Fire Training area and Nant y Stepsau brook were not observed due to hedgerows along Eglwys Brewis Road and locked access gates belonging to the St. Athan MoD site.

3.3 Geomorphological/Geological Mapping

The geomorphology of the area is governed by the underlying Jurassic stratigraphy. The relief in this stage is very low and the topography is planar which reflects the lacustrine and mature alluvial origin of the upper sediments.

3.4 Ground Investigations

3.4.1 Description of Fieldwork

The scope of the ground investigation was designed on the basis of the AECOM Alignment drawings (Drawing No: 60509148-SHT-30-0000-CT-0601 to 0604) enclosed in Appendix A. The key objectives were as follows:

- Confirm the ground model across the St. Athan site
- Provide additional information on ground conditions and guidance on subgrade conditions along the proposed alignment;
- Provide information on the engineering properties of the soils on site;
- Ascertain the infiltration characteristics of the ground;
- Recover samples of soils and/or groundwater;

- Undertake in-situ and laboratory geotechnical testing of soils.

AECOM Infrastructure & Environment UK Limited was appointed as the specialist site investigation contractor for the works.

The techniques used to investigate the geotechnical properties of the ground were generally in accordance with Eurocode 7: Geotechnical Design- Parts 1 and 2 (BS EN 1997-1:2004, BS EN 1997-2: 2007).

The identification and description of soils in the ground investigation has been undertaken in accordance with Geotechnical Investigation and Testing- Identification and Classification of Soil (BS EN ISO 14688-1:2002) and Code of Practice for Site Investigations (BS5930:1999 as amended).

A copy of the combined Factual Report, covering the supplementary investigation undertaken in November 2016, is provided in Appendix D.

3.4.2 Description of Fieldwork

The fieldworks were carried out in the period between 21st November and 2nd December 2016.

3.4.3 Exploratory Holes

3.4.3.1 Machine Excavated Trial Pits

Eleven (11 No.) trial pits, designated SK501 to SK510 and TP501 were excavated to depths of 0.7m and 1.4m below ground level. All trial pits were terminated on shallow bedrock (Porthkerry Member) and therefore not completed to their scheduled depth, the details of which are described in Table 3.0. The remains of a wall of archaeological interest were discovered during the excavation of SK501. Hence, the exploratory hole was relocated east away from the area of interest.

Table 3.0: Revised Depths of Exploratory Holes

Exploratory Hole ID	Description	Scheduled Depth (m bgl)	Completed Depth (m bgl)
SK501	Trial Pit (Soakaway)	1.5	1.4
SK502	Trial Pit (Soakaway)	1.5	0.7
SK503	Trial Pit (Soakaway)	1.5	1.3
SK504	Trial Pit (Soakaway)	1.5	0.8
SK505	Trial Pit (Soakaway)	1.5	0.9
SK506	Trial Pit (Soakaway)	1.5	1.2
SK507	Trial Pit (Soakaway)	1.5	0.9
SK508	Trial Pit (Soakaway)	1.5	0.95
SK509	Trial Pit (Soakaway)	1.5	1.32
SK510	Trial Pit (Soakaway)	1.5	1.4
TP501	Trial Pit	1.5	1.4

The depths of the exploratory holes, descriptions of strata encountered and comments on the groundwater conditions are given in the exploratory hole records (Appendix D). Figure 2 identifies the positions of the exploratory holes.

It is important to note that groundwater levels given in the exploratory hole records may not reflect true equilibrium conditions for a number of reasons. For example, water may have been added to assist drilling, or alternatively the water may not have reached an equilibrium level within the standing time.

On completion of logging, trial pit soakaway tests were performed in ten trial pits (SK501 to SK510). The tests were carried out broadly in accordance with the procedure in BRE Digest 365 (Ref. 11). In brief, each trial pit was filled with water pumped from a bowser to the specified invert level and water levels were recorded versus time. The BRE Digest 365 requires three tests to be performed but due to slow soakage rates only one test was performed at each location. The results of the soakage tests are presented in Appendix D.

Following completion of logging and sampling, all trial pits were backfilled with soil arising compacted in layers.

3.4.3.2 Rotary Boreholes

Four (4 No.) boreholes, designated BH501 to BH504 were advanced by rotary percussive followed by rotary core drilling methods to depths between 8.0m and 8.5m bgl.

3.4.4 Groundwater Monitoring Wells

Standpipe piezometer wells were installed in all of the boreholes (BH501 to BH504).Three monitoring visits have been undertaken (8th December 2016, 9th January 2017 and 9th February 2017. Details of the piezometer installations are water levels are summarised in Appendix D.

3.4.5 Results of In Situ Tests

3.4.5.1 Hand Shear Vane Tests

Twenty-one (21 No.) in situ hand shear vane tests were carried out in the cohesive strata encountered in the trial pits and boreholes as presented on the exploratory logs within the AECOM Factual Report (Appendix D).

3.4.5.2 Standard Penetration Tests

Seven (7 No.) Standard Penetration Tests were performed at varying depths within the boreholes in accordance with BS EN ISO 22476 – 3:2005+A1:2011 (Ref.12). The results are included on the exploratory hole logs in Appendix D.

3.4.5.3 Dynamic Cone Penetrometer Tests

Eleven (11 No.) Dynamic Cone Penetrometer Tests were performed from the base of all of the trial pits. The DCPs were unable to attain the schedule depth due to shallow bedrock. The detailed logs are presented in Appendix D.

3.4.5.4 Soakaway Tests

Falling head soakaway tests were carried out in 10 No. trial pits (SK501 – SK510), in accordance with the Soakaway Design Guide (Ref.11). The results of the tests are included in Appendix D.

3.5 Laboratory Investigation

3.5.1 Description of Tests

A programme of laboratory testing, scheduled by AECOM, was carried out on samples taken from the various strata. The geotechnical laboratory tests were carried out by GEO Site & Testing Services Ltd; a UKAS accredited lab. The test procedures used were generally in accordance with the methods described in BS 1377:1990 (BSI).

The testing schedule is summarised as follows:

- Natural Moisture Content (8 No.)
- Atterberg Limits (7 No.)
- Particle Size Distribution – Wet sieve (5 No.)

- Uniaxial Compressive Strength (2 No.)
- Laboratory Vane (shear strength) (3 No.)
- Point Load Tests (4 No.)
- Suite D – Brownfield with Pyrite (4 No.)
- Compaction Tests – 2.5kg or 4.5kg (3 No.)
- California Bearing Ratio (CBR) (6 No.)
- Slake Durability Tests (4 No.)

4. Ground Summary

4.1 Summary of Ground Conditions

Borehole logs are presented in the AECOM Factual Report (Appendix D). The exploratory holes encountered Made Ground and Topsoil overlying Alluvium and the Porthkerry Member. The investigation highlighted the presence of Alluvium across the site which was not suggested by the published geological records. There a number of watercourses which intersect the site and as such the presence of Alluvium cannot be discounted.

A summary of the general succession of strata is presented in Table 4.1 and a geological cross-section taken through the site is enclosed in Appendix E. The thickness of the Porthkerry Member was not proven.

Table 4.1: Summary of Ground Conditions

Stratum	Depth of Top of Stratum m bgl (m AOD)	Thickness (m)
Topsoil	G.L. (41.53 – 44.96)	0.25 – 0.45
Made Ground	G.L. – 0.25 (43.01 – 44.71)	0.4 – 0.65
Alluvium	0.2 – 0.45 (41.46)	0.35 – 2.2
Porthkerrry Member	0.35 – 2.4 (41.18 – 39.49)	Unproven (max thickness 7.8m)

G.L.:Ground Level

4.2 Topsoil

4.2.1 Description

Topsoil was encountered across the entire site. The top of the stratum was encountered at ground level and ranged in thickness from 0.25 to 0.45m. The material was generally described as grass over soft dark brown slightly gravelly sandy CLAY with frequent rootlets. The gravel is limestone.

4.3 Made Ground

4.3.1 Description

Made Ground was encountered in three exploratory holes along the western extent of the road predominantly in the area of archaeological interest. The Made Ground was encountered at ground level with the exception of one discrete area where it was encountered beneath the topsoil. It ranged in thickness from 0.4m – 0.65m. The material was generally described as soft becoming firm slightly sandy gravelly CLAY with abundant roots. Gravel is limestone, brick and mudstone.

4.4 Alluvium

4.4.1 Description

Alluvium was encountered in the exploratory holes across the site. The surface of the Alluvium was encountered at depths ranging from 0.2m to 0.45m. The thickness of the deposit ranged from 0.35m to 2.2m. The material was generally described as soft becoming firm yellowish brown slightly gravelly CLAY. The gravel is limestone and mudstone. A geological section illustrating the variation in the surface and thickness of the Alluvium is enclosed in Appendix E.

4.4.2 Standard Penetration Testing

One (1 No.) in-situ Standard Penetration Tests (SPTs) was undertaken within the Alluvium. The corrected SPT "N" value (N_{60}) recorded was 13. This indicates the material to be soft to firm in strength.

4.4.3 Natural Moisture Content

Seven (7 No.) moisture content results were derived from samples recovered from the Alluvium at varying depths, and the natural moisture content ranged from 19% to 39% (average 32%). The results of the moisture content tests are plotted against depth in Figure 3. Generally, the results suggest the moisture content of the material decreases with depth.

4.4.4 Atterberg Tests

Seven (7 No.) Atterberg Tests were undertaken on samples collected from the Alluvium. The plastic and liquid limits ranged from 23% to 34% (average 29%) and 46% to 62% (average 57%). The plasticity index ranges from 23% to 30% (average 27%). These results generally classify the material as clay or silt as of intermediate to high plasticity. The plasticity chart for the Alluvium is given in Figure 4.

The modified plasticity index, as defined in the NHBC Standards 2014 (Ref. 17) ranges from 19 to 22 (average 21) which classifies the material as medium volume change potential.

4.4.5 Undrained Shear Strength

The undrained shear strength of the material has been derived from lab shear vanes, corrected hand shear vane tests (Bjerrum, 1972) and after the empirical correlation by Stroud (1974).The results indicate the material has an undrained shear strength of between 30 kN/m^2 to 69 kN/m^2 (average 47 kN/m^2) which classifies the material as soft to firm. A plot of undrained shear strength against depth is presented in Figure 5. There is no clear relationship between undrained shear strength and depth.

4.4.6 Particle Size Distributions (PSD)

Two PSD tests were undertaken on bulk samples collected from the Alluvium. The results indicate the material consists of on average silt and clay (41%), sand (26%), gravel (25%) and cobbles (17%). The results of all the PSD tests are illustrated on Figure 6. Based on these PSD results it is not anticipated that this material will be acceptable for re-use.

4.4.7 California Bearing Ratio (CBR) Tests

CBR tests were undertaken on samples collected from Alluvium between 0.35m bgl and 0.83m bgl. Five (5 No.) CBR tests were undertaken in the laboratory and two results were derived from DCP tests. The results from the lab results indicate the Alluvium generally has a CBR of between 0.5% and 2%. The DCP tests recorded values of 17% and 100% respectively. Both results were undertaken from 0.8m bgl. This suggests the material either becomes firm below this level or it could be attributed to discreet areas of more granular material. The results are illustrated on Figure 7.

4.5 Porthkerry Member (Blue Lias Formation)

4.5.1 Description

The Porthkerry Member was encountered in all of the exploratory holes. The base of this unit was not encountered but it was proven to a maximum thickness of 7.8m. The top of the Porthkerry Member ranged from 0.35m bgl to 2.4m bgl. The material is generally described as medium strong to extremely weak grey weathered LIMESTONE with subhorizontal and subvertical closely spaced open fractures infilled with soft dark brown slightly sandy silty clay. The Rock Quality Designation (RQD) classifies the rock as poor to excellent. Generally, this represents sections of densely fractured rock intermittent with thick bands of good to excellent rock.

4.5.2 Standard Penetration Testing

Six (6 No.) in-situ Standard Penetration Tests (SPT's) were undertaken within the Porthkerry Formation. All of the values recorded were greater than 50. This would indicate a hard strata.

4.5.3 Particle Size Distributions (PSD)

PSD testing was undertaken on three bulk samples collected from 0.6mbgl and 1.3mbgl. The results indicate the weathered material comprises of approximately 20% silt and clay, 13% sand, 53% gravel and 14% cobbles. The results of all the PSD tests are illustrated on the PSD plot in Figure 8.

4.5.4 Point Load Tests and Unconfined Compressive Tests (UCS)

Four Point Load Tests were undertaken on samples collected form the Porthkerry Member between 1m bgl and 8m bgl. The results ranged from 1.5 MPa to 16.4 MPa (average 3.8 MPa). Unconfined Compressive Tests were undertaken in the laboratory (2 No.) and derived from the point load tests (UCS = 20 I_s). The results ranged from 29.4 MPa to 327 MPa (average 78.5 MPa). These results classify the material strength as moderately strong to very strong rock.

The results indicate there are alternating bands of less and more competent material up to 4 m bgl after which the strength of the material increases significantly up to 5.5m bgl and then decreases in strength up to 8m bgl. This suggests there is a thick bed of limestone with minimal fracturing between 4.0m bgl and 5.5m bgl. The results are illustrated in Figures 9 and 10.

4.5.5 California Bearing Ratio (CBR) Tests

Nine (9 No.) CBR tests were derived from in-situ DCP tests undertaken within the Porthkerry Member between 0.8m bgl and 2.0m bgl. The results indicate the material has a CBR value of between 4% and 100% (average 65%). The results indicate there are intermittent bands of weaker and stronger material which is interpreted to be areas of rock with clay infill and more competent material. The results are illustrated on Figure 7.

4.6 Groundwater

Groundwater was encountered during fieldwork at the depths indicated in Table 4.2.

Table 4.2: Summary of Groundwater Observations during Fieldwork

Borehole	Strike m bgl (m AOD)	Rise m bgl (m AOD)	Stratum
SK503	1.3 (42.88)	1.2 (42.78)	Weathered Porthkerry Member
SK504	0.8 (42.46)	0.7 (42.36)	Weathered Porthkerry Member
SK507	0.8 (41.22)	No rise recorded	Weathered Porthkerry Member
SK508	0.95 (41.02)	0.6 (40.67)	Weathered Porthkerry Member
SK509	1.2 (40.51)	1.1(40.41)	Alluvium
BH501	1.3 (41.71)	No rise recorded	Weathered Porthkerry Member
BH502	0.7 (41.29)	1.2* (41.79)	Alluvium
BH503	1.2 (40.63)	No rise recorded	Weathered Porthkerry Member
BH504	0.8 (41.11)	1.35* (41.66)	Weathered Porthkerry Member

*Water level fell

The results of the groundwater monitoring programme undertaken following the completion of boreholes is summarised in Table 4.3.

Table 4.3: Summary of Groundwater Monitoring Results

Borehole	Depth (m bgl)		Elevation (m AOD)		Stratum
	Min	Max	Min	Max	
BH501	1.37	3.8	41.64	39.21	Weathered Porthkerry Member
BH502	0.6	2.3	41.29	39.59	Alluvium
BH503	1.2	1.35	40.6	40.45	Weathered Porthkerry Member
BH504	1.26	1.47	40.65	40.44	Weathered Porthkerry Member

The findings indicate groundwater is present within the Alluvium at a level between 40.5m AOD and 41.3m AOD. Groundwater within the Porthkerry Member is situated between 40.6m AOD and 42.9m AOD. Groundwater levels are likely to be susceptible to fluctuations in level as a result of variations in precipitation.

4.7 Summary of Geotechnical Parameters

A summary of geotechnical parameters for the principal geological units is provided in Table 4.4.

Table 4.4 Summary of Geotechnical Parameters

Alluvium			
Parameter	**Unit**	**Value / Range (average)**	**Justification**
C_u	kN/m^2	30 – 69 (47)	Field Hand Shear Vane Tests (Bjerrum, 1960 correlation- applicable for soft clays); Lab Shear Vane Tests; Stroud (1975) correlation;
ϕ’	degrees	28	Bjerrum and Simons (1960)
Bulk Density	kN/m^3	17.5	Lab test results
Dry Density	kN/m^3	13.5	Lab test results
SPT-N_{60} (corrected)	-	12*	In situ test
Moisture content	%	30 – 39+ (33)	Lab test results
Plasticity/Modified Plasticity Index	%	19.5 – 21.8 (20.6)	NHBC (2014)
Plastic Limit	%	23 – 34 (29)	Lab test results
Liquid Limit	%	46 – 62 (57)	Lab test results
Volume Change Potential	-	Medium	NHBC (2014)
CBR	%	0.5 – 2 (1.1)	Lab test results
Pothkerry Member			
Parameter	**Unit**	**Value / Range**	**Justification**
ϕ’	degrees	35	Literature values – Waltham, 2009
Bulk Density	kN/m^3	15	Lab test results
Dry Density	kN/m^3	12	Lab test results
SPT-N (uncorrected)		>50**	In situ test
Moisture content	%	0.45 – 1	Lab test results
Point Load	MPa	1.47- 6.9*** (3.5)	Lab test results
UCS	MPa	29.4 – 159 (72.5)	Lab test results and Waltham 2009 correlation (20*I_S)
CBR	%	4 – 100 (65)	DCP Tests

* one value recorded; ** all values recorded were >50; *** one value recorded over 6.9 – value recorded as 16.4; **** one value over 159

+ one MC value recorded as 19% but this is considered to be non-representative

4.8 Soakaways

The soil infiltration characteristics were to be assessed by means of a falling head test in accordance with the method given in the BRE Digest “Soakaway Design”, 2007 (Ref. 11). The Digest requires three tests to be carried out at each location but extremely slow infiltration rates meant that only one test was completed before the pit was backfilled.

Due to the slow infiltration rate it was not possible to calculate the design infiltration value, however the ground conditions do not appear suitable for the use of pit soakaways.

4.9 Visual and Olfactory Evidence of Contamination

Made Ground can be seen on site which could be a potential source of contamination. No visual and/or olfactory evidence of contamination was recorded.

5. Geotechnical Risk Register

5.1 General

A preliminary risk register is presented highlighting the potential geotechnical risks of the project. The risk register shall be revisited and updated to take into account new information obtained during the design process. The risk scoring system detailed below has been adopted.

Table 5.1: Risk Scoring System

Probability (P)		Impact (I)					RISK (R = P x I)	Response to Risk
Very Probable	5	Very High	5	Potential to halt the project	OR	Potential for major claim or similar	17 to 25	Unacceptable: act now to present
Probable	4	High	4	Significant delay on overall project		Major impact on cost	13 to 16	Unacceptable: act now to prevent
Possible	3	Medium	3	Major delay on this task, but significant impact on overall project unlikely		Significant impact on cost	9 to 12	Early attention required
Unlikely	2	Low	2	Minor delay on this task, but significant impact on overall project unlikely		Minor impact on cost	5 to 8	Regular attention required
Negligible	1	Very Low	1	No significant impact on task or project		Negligible impact on cost	1 to 4	Monitor

5.2 Geotechnical Risks

The Geotechnical Risk Register is presented overleaf.

Identified Geotechnical Hazard/Risk	Cause	Risk before Control			Consequence	Feature Affected	Control Measures	Risk after Control		
		P	I	R (P*I)				P	I	R (P*I)
GENERAL ROUTE AND STRUCTURES										
Variable ground/variable strength material	Alluvium and Porthkerry Member	3	4	12	Performance of road pavement compromised and/or deterioration of subgrade Reduced service life Maintenance costs Increased overall cost Commuter safety compromised Closure of road Potential instability of structures founded in Alluvium	Whole route	Remove, replace or otherwise enhance compressible/weak material Monitor settlement of road pavement Based on findings of monitoring, increase maintenance or design remedial solutions	1	4	4
Encountering unexpected	Inadequate/ no service or hazard	3	4	12	Injury to contractor's staff, AECOM personnel and	Whole route	Appropriate surveys and searches to be completed and made available to	1	4	4

Identified Geotechnical Hazard/Risk	Cause	Risk before Control			Consequence	Feature Affected	Control Measures	Risk after Control		
		P	I	R (P*I)				P	I	R (P*I)
services	plans				the general public Potential prosecution and compensation claims Significant programme delays Disruption to service provided by statutory holders		contractor prior to commencement of site works On site cable avoidance tools to be utilised in accordance with HS (G) 47 Inspection pits to be dug for any intrusive works			
Shallow Groundwater	Groundwater encountered between 0.7m bgl – 1.3m bgl during recent ground investigation	4	3	12	Performance of road pavement compromised and/or deterioration of subgrade Instability of excavations Difficulties during construction Significant programme delay		Consider groundwater control measures Incorporate appropriate drainage measures during detailed design stage Assess frost susceptibility of material	3	3	9

Identified Geotechnical Hazard/Risk	Cause	Risk before Control			Consequence	Feature Affected	Control Measures	Risk after Control		
		P	I	R (P*I)				P	I	R (P*I)
					Increased cost					
Injury to contractor's staff and AECOM personnel during construction	Soft ground and highly fractured rock Inadequately trained staff Unexpected site conditions	2	3	6	Injury to contractor's staff and AECOM personnel Delays to programme Compensation claims	Whole route	Utilise suitable site plant for ground conditions Shoring of excavations where appropriate Should unexpected groundwater be encountered due to localised pockets of more granular material or other unique site conditions work should cease and advice sought from a suitably qualified engineer on site. All personnel should be suitably qualified for the	1	3	3

Identified Geotechnical Hazard/Risk	Cause	Risk before Control			Consequence	Feature Affected	Control Measures	Risk after Control		
		P	I	R (P*I)				P	I	R (P*I)
							respective tasks (minimum CSCS qualification for visitors on site)			
Presence of contaminated land	Prior/ current site use leading to the presence of contaminants on site	3	3	9	Injury to contractor's staff Delays to programme Increased project cost	Entire route	Assess potential for contaminated land prior to commencement of construction works Ensure staff are adequately trained and informed Use appropriate PPE	1	3	3
Flooding (proposed road in the vicinity of Boverton Brook and Llanmaes Brook)	Boverton Brook and Llanmaes Brook in vicinity and crossing road alignment	3	3	9	Flooding of excavations Damage to site machinery and equipment Increased risk of water borne diseases	Whole route	Monitor water levels in Boverton and Llanmaes Brook and check weather forecast daily to ensure safety of site staff Programming of works	2	3	6

Identified Geotechnical Hazard/Risk	Cause	Risk before Control			Consequence	Feature Affected	Control Measures	Risk after Control		
		P	I	R (P*I)				P	I	R (P*I)
					Safety of site staff compromised Programme delays Increased cost					
Unforeseen ground conditions	Error in geological mapping or unforeseen ground conditions due to history of site	2	3	6	Construction delays and redesign	Entire route	Use findings of desk study and project specific intrusive ground investigation to improve the accuracy of ground models	1	3	3
Encountering unexploded ordnance	Encountering UXO due to site history	3	4	12	Delays caused by clearance works or initiation - endangering life	Whole route	Adopt appropriate mitigation measures as listed in historical reports. Reassess risk during each project/construction phase.	2	4	8

Identified Geotechnical Hazard/Risk	Cause	Risk before Control			Consequence	Feature Affected	Control Measures	Risk after Control		
		P	I	R (P*I)				P	I	R (P*I)
Encountering hard strata at shallow depths	Limestone (Porthkerry Member) encountered at shallow depths	4	3	12	Delays as a result of difficulties with excavations using conventional means Increased cost associated with the use of specialist equipment	Entire route	Incorporate findings of desk study and project specific intrusive ground investigation during design process. Utilise suitable site plant for ground conditions	4	2	8
EMBANKMENTS/CUTTINGS										
Slope instability/failure	Inadequate compaction, soft deposits, collapse	3	3	9	Failure of slope construction Requirement for emergency works Damage to services and essential road furniture (e.g. safety barriers)	All earthworks along scheme	Implement slope stabilising measures, drainage and planting of vegetation Construct and adequately maintain slope drainage Allow for long-term	1	3	3

Identified Geotechnical Hazard/Risk	Cause	Risk before Control			Consequence	Feature Affected	Control Measures	Risk after Control		
		P	I	R (P*I)				P	I	R (P*I)
					Reduced service life Increased cost associated with maintenance Temporary road closure Delays to programme		monitoring of slopes			
Unacceptable of site won material for reuse	Soft deposits and massive rock	3	3	9	Potential disposal off-site and associated Cos Earthworks cut and fill imbalance requiring importation of fill	Embankments and cuttings along scheme	Careful earthwork materials site management Materials conditioning	2	3	6

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Figures

Appendix A – AECOM Alignment Drawings

Appendix B – Previous Investigation Reports

Appendix C – Envirocheck Report

Appendix D – AECOM St. Athan Northern Access Road – Factual Ground Investigation Report

Appendix E – St. Athan NAR Geological Cross-Section

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