Newton Stewart
FLOOD PROTECTION SCHEME

NEWTON STEWART FLOOD PROTECTION SCHEME – SUPPORTING DOCUMENT
GROUND INVESTIGATION INTERPRETATIVE REPORT

118908/DOC/300/001

07 DECEMBER 2018

SWECO UK LIMITED

Dumfries & Galloway COUNCIL

SWECO

Change list

VER.	DATE	CHANGE CONCERNS	ORIGINATOR	REVIEWED	APPROVED
1	07/08/18	DRAFT FOR COMMENT	SML	RS	NPT
2	25/08/18	UPDATED FOLLOWING COMMENTS	SML	RS	NPT
3	07/12/18	FORMATTING AMENDED	ARW	RS	NPT
4	18/05/2020	MINOR FORMATTING	ARW	RS	NPT

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1 Introduction

1.1 Scope and Objective of the Report

On behalf of Dumfries and Galloway Council (DGC) Sweco has prepared a geotechnical and geo-environmental Interpretative report to support the design of the flood alleviation structures in the Newton Stewart area. The Scheme title "Newton Stewart Flood Protection Scheme", referred to herein after as the Scheme.

The report has been prepared to summarise and interpret geotechnical and geo-environmental information for the completed intrusive ground investigation undertaken between 13th December 2017 and 23rd February 2018 within the Scheme. The report presents the findings of all the studies and investigations undertaken for the Scheme along with historical ground investigation records made available by DGC. Geotechnical and geo-environmental recommendations emerging from the investigation findings are provided to support the outline design and future construction of the proposed flood alleviation works.

1.2 Description of the Project

1.2.1 Site Location and Description

The Scheme area comprises approximately 37 hectares (ha) of land surrounding the River Cree as it flows through the town of Newton Stewart, excluding Minnigaff in the north. The Cree bridge crosses the River Cree approximately in the northern half through the Scheme. The site for the Proposed Sparling Bridge is captured by the Scheme area, therefore information gathered from this area will be included within this report. However, Sparling Bridge will be subject to separate factual and interpretative reporting to aid design.

Land uses are predominantly residential in the north and central site areas with commercial and industrial units located along the western bank of the River Cree at the southern extent of the site. The eastern bank of the River Cree at the south of the site is bounded by grazing fields. The Holmpark Industrial Estate is located at the very eastern extent of the site area, to the east of the River Cree.

The site is approximately centred on Ordinance Survey Grid Reference NX411656 and its location is presented in **Figure 1.1**.

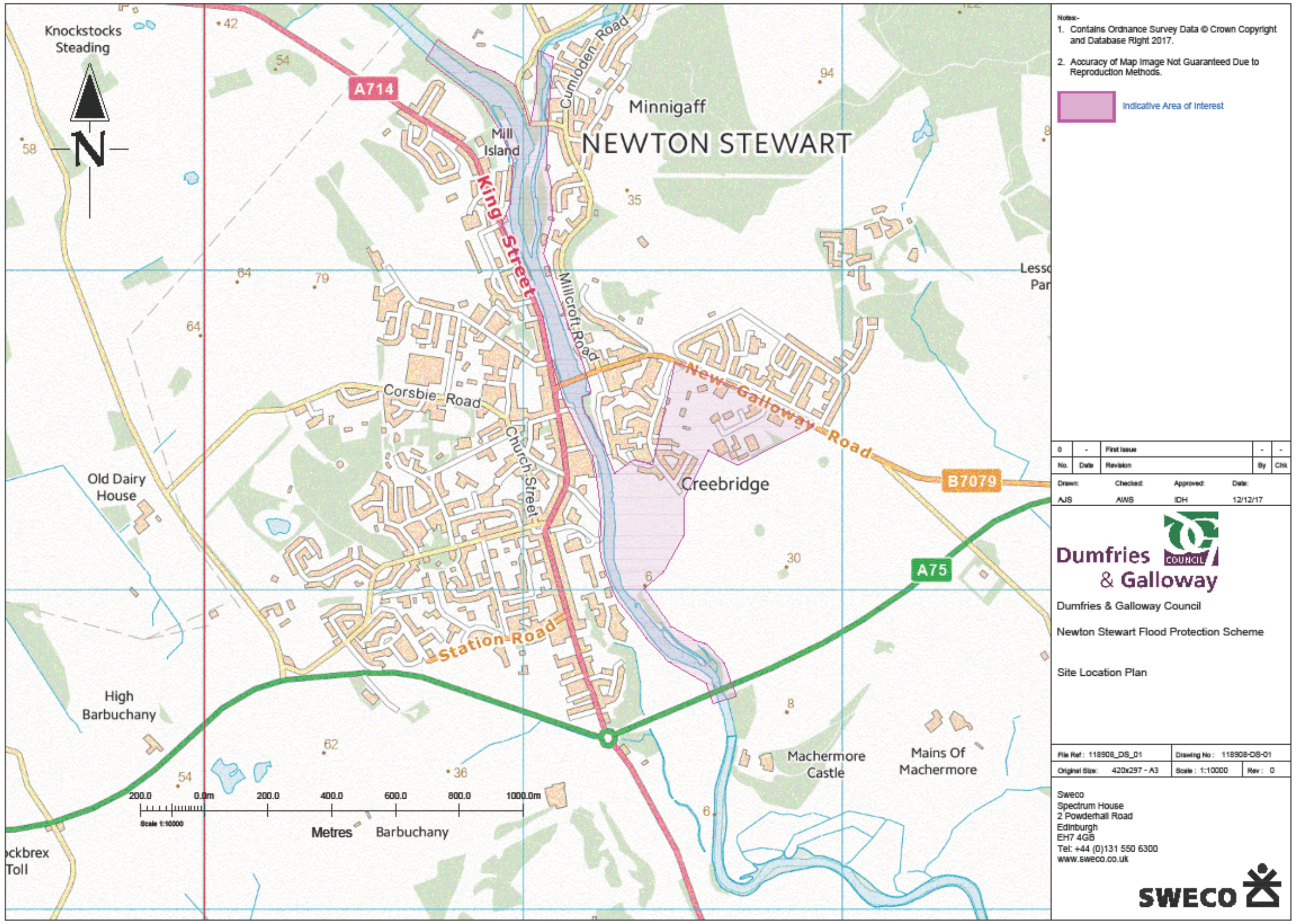

Figure 1.1: Site Location (Contains Ordnance Survey Data Crown Copyright and Database Right 2018)

1.2.2 Project Description

The preferred scheme comprises the following Design Options:

- Option 6 – Construction of direct defences (within Newton Stewart) comprising walls embankments and extending existing defences;
- Option 7 – Increase flow beneath A75 bridge through regrading of the River Cree bank to create a duel channel and reduce channel material, increasing flow;
- Option 24 – Reprofile flood plain land around pumping station to increase attenuation during flooding events; and
- Construction of Sparling Bridge.

The design at present for the Scheme is included in **Appendix A.**

It is noted that this report applies to Newton Stewart only, and does not include works within the scheme located in Minnigaff, east of the River Cree and north of the Cree Bridge. The investigations associated with the scheme in this location will be reported in a separate, addendum report following completion of the scheduled intrusive investigations.

2 Previous Reporting

2.1 General

A number of reports focused on the geotechnical and geo-environmental characteristics of the site have been prepared in the past.

These reports were used to obtain background information on the history of the area, including land use, flood records, environmentally sensitive areas, and ground conditions.

The available information is as follows:

- Sweco Ltd. Newton Stewart Flood Prevention Desk Study. 118908/DS. Dated 08th September 2017;
- Sweco Ltd. Factual Geo-environmental Desk Study Report, Newton Stewart Flood Protection Scheme. 118908. Dated 9the January 2018;
- Kaya Consulting Limited. Newton Stewart: Outline Flood Mitigation Options – Addendum. April 2017; and
- Ian Farmer Associates. Sparling Footbridge, Newton Stewart Report on Ground Investigation. July 2017.

The above Sweco desktops were prepared initially to capture the multiple Options in September 2017, and further refined in the January 2018 reporting for Options 6, 7 and 24.

This section provides a summary of the information pertinent to the Scheme obtained from the reports listed above. Information provided in the subsequent sections is based primarily on the Sweco Desk Study and recent ground investigation, supplemented where relevant by the aforementioned historical reporting.

2.2 Topography

The topography of the Scheme is dictated largely by the River Cree and it's tributary Penkiln Burn flowing north to south through the study area.

Regionally the Scheme is at a lower elevation to the surrounding hills. Generally, the site is gently sloping southward with average heights of 30m AOD at Minnigaff and 8m AOD in the south where the A75 crosses the River Cree.

2.3 Geological Setting

This section summarises the published geology sourced from the British Geological Survey (BGS) Map Sheet 4E Wigton (1:50 000 scale) Solid (1992), and Drift Edition (1981), and the resources available online.

The majority of the Scheme is underlain by alluvium, raised marine beach deposits and glacio-fluvial deposits. These soils are associated with the water courses in the area and regional past glaciation events. Solid strata are recorded to comprise Silurian and Ordovician Greywackes.

There is one previous ground investigation within the site area, targeting the proposed Sparling Bridge structure. The ground investigation and report was undertaken by Ian Farmer Associates, titled Sparling Footbridge, Newton Stewart Report on Ground Investigation, July 2017.

The BGS Geoindex identifies eleven historical exploratory boreholes located on or within the immediate vicinity of the site, which are discussed below.

Sweco has reviewed the ground investigation and historical borehole logs pertinent to the Scheme with three logs from Ian Farmer Associates 2017 and eleven BGS historical boreholes. Based on these records, an existing ground conditions profile was summarised as shown in Table 2.1

Table 2.1: Ground Conditions Summary- Historical Investigations

Strata	Depth* (m bgl)
Topsoil	GL - 0.1/ 0.6
Made Ground	GL/0.1 - 1.1/ 4.4
Alluvium	GL/ 4.1 - 2.4/7
Raised Marine Beach	3.05 - 16.15
Glacio-Fluvial	Not Encountered
Glacial Till	Not Encountered
Bedrock	Not Encountered
Groundwater	1.67 - 5.45

Notes

* from top depth range recorded to base depth range recorded

m bgl: metres below ground level

GL: ground level

2.3.1 Topsoil

Topsoil was recorded in boreholes BH1, BH2 and BH3 to a maximum depth of 0.6m, recorded generally as grass overlying gravelly sand.

2.3.2 Made Ground

Available geological mapping indicates no artificial deposits across the Scheme. However, made ground is anticipated across the site area, associated with the urban development and farming land use.

Made ground was encountered in historical boreholes referenced NX46NW7, NX46NW8, NX46NW9 and NX46NW10, located on the east bank of the confluence point between the River Cree and Penkiln Burn. Typically, this comprised Fill material, an assortment of brick, boulders, rubble, sands and gravel.

2.3.3 Superficial Deposits

Mapping indicates a complex system of mixed alluvial, glaciofluvial and raised marine deposits, in and around the town of Newton Stewart. The BGS maps indicate Raised Marine Beach deposits, comprising gravel, sand and silt are recorded to the south and east of the A75 bridge extending north towards Creebridge.

These are likely underlain by Glacial Till in the western extents of the Scheme.

The River Cree valley and Penkiln Burn valleys are dominated by alluvial deposits of silt, sand and gravel, with localised glaciofluvial deposits of gravel, sand and silt.

No superficial deposits are recorded in the north west of the scheme, superficial deposits are therefore anticipated to be minimal in this area.

Alluvium was encountered across the Scheme in all BGS boreholes (11 inclusive) and the Ian Farmer Associates three boreholes targeting Sparling Bridge. Deposits varied between loose to very dense sandy gravels with Standard Penetration Test (SPT) N values ranging from 9 to 50. Additionally, stiff clay with an SPT N value of 20 was observed.

Basal Granular Materials were recorded in BGS borehole, reference NX46SW742/106, located immediately outside the Scheme south west extent, on the A75. This comprised compact gravel with a little sand and occasional cobbles and boulders. It is likely that these deposits are associated with glaciofluvial deposits and raised marine beach deposits.

2.3.4 Solid Geology

Regionally, the solid geology is dominated by the Greywacke formations of Silurian and Ordovician age. Within the Scheme, the bedrock is anticipated to comprise the Gala Group wackes, characterised by sequential sandstones, siltstones and mudstones.

In addition to this, there are calc-alkaline dykes noted within this unit, generally trending NE-SW. There are noted sporadically out with the Scheme, however it would not be unusual for these to be observed intruding into the wackes on site.

Two faults, downthrown westwards are recorded trending NW-SE through the Scheme. These can be observed running approximately parallel with each other, intersecting the River Cree. The displacement associated with these features is not indicated . Regionally, these faults are accompanied by numerous faults trending parallel and perpendicular throughout the Greywacke formations.

Bedrock was not encountered in previous ground investigations where the maximum depth bored was 16.15m bgl in the Scheme in historical borehole NX46SW742 106.

2.3.5 Hydrology

The SEPA River Basin Management Planning (RBMP) interactive map viewer has been reviewed to identify water body information for water courses within the Scheme, which identify the River Cree and Penkiln Burn.

SEPA has classified the River Cree as having an overall status of Moderate with Medium confidence in 2008 with an overall ecological status of Moderate and an overall chemical status of Pass.

SEPA has classified the Penkiln Burn as having an overall status of Good with Medium confidence in 2008, with an overall ecological status of Good and an overall chemical status of Pass.

2.3.6 Hydrogeology

The Hydrogeological Map of Scotland (1:625,000 scale, 1988) shows the Scheme is underlain by Silurian and Ordovician rocks which are regarded to be impermeable except at shallow depths. Overlying impermeable bedrock, it is considered likely that locally important aquifers within Quaternary sands and gravels and river alluvium will be present.

The Groundwater Vulnerability Map of Scotland (1:625,000 scale) indicates that the Scheme is underlain by a weakly permeable aquifer that does not widely contain groundwater in extractable quantities. Regionally, the Gala Group is noted to seldom produce large quantities of water for abstraction but is important for local supplies and in supplying base flow to rivers. It is also noted that superficial drift deposits overlie the area which can sometimes be substantial in thickness. Although often variable in composition, these are indicated on the map to be moderately permeable.

The online SEPA RBMP interactive map identifies groundwater bodies underlying the area of interest. The following sections summarise available groundwater body information.

SEPA has classified the quality of water within the Newton Stewart Bedrock Aquifer as having an overall status of Good with High confidence in 2008. The quantity of groundwater has been classified as Good with high confidence in 2008.

Groundwater was observed in historical boreholes between 1.67m and 5.45m bgl within Alluvium. Groundwater monitoring was not continued in the historical boreholes beyond the initial readings.

2.4 Aerial Photography

The interactive digital aerial photography available from Google Maps (https://www.google.co.uk/maps/place/Newton+Stewart) provides aerial photographs and the street view allows a review of the majority of the site and confirms the description in Section 1.2.1.

In addition, a review of the Google Earth information provides information from 2005 and 2015 aerial mapping confirming descriptions included in Section 2.6.1.

2.5 Historical Mining / Mineral Extraction

The Coal Authority interactive mapping indicates that the site does not fall within a Coal Mining Reporting area and there are no known records of coal mining.

The BGS Mining Plan Portal for mining and non-coal mining activities was consulted. The Wood of Cree Mine (1919) lead and copper mine is identified (circa 4km NW) out with the Scheme. No mining activities within influencing distance of the site were encountered.

2.6 Land Use Past and Present

2.6.1 Historic Land Use

Online historical maps have been reviewed, and are publicly available at the National Library of Scotland. In addition, an Envirocheck Report was procured, providing historical maps for the Scheme. The following sections provide an outline summary of historical development within proximity of the Scheme. Drawings detailing the historical feature locations are available in the Sweco Newton Stewart Flood Protection Scheme, Factual Geo-environmental Desk Study Report, January 2018.

Table 2.2: Key Historic Land Uses

Dates		Historic Feature	Within Site
From	To		
c.1895	c.1908	Heugh Mill (Corn)	✓
c.1895	c.1908	Minnigaff Mill (Corn)	✓
c.1895	c.1908	Brewery	✓
c.1895	c.1908	Gravel Pit	✓
c.1895	c.1908	Minnigaff Sawmill	✓
c.1895	c.1908	Clay Pit	X
c.1895	c.1990	Gasworks	X
c.1895	c..1991	Mill Lead (at Minnigaff Corn Mill)	✓
c.1895	Present	Mill Lead (at Heugh Mill / Cree Mills / Brewery)	✓
c.1895	c.1908	Mill Lead (at Minnigaff Sawmill)	✓
c.1895	Present	Grave Yard	X
c.1908	-	Reservoir (at Cree Mills)	X
c.1908	c.1989	Slaughterhouse	X
c.1908	c.2005	Cree Mills (Woollen Mill)	✓
c.1970	c.1977	Sewage Works	✓
c.1970	c.1996	Telephone Exchange	X
c.1970	c.1996	Works	X
c.1970	Present	Sewage Works	X
c.1970	Present	Tank	✓
c.1985	-	Electrical Substation	X
c.1985	c.1993	Electrical Substation	✓
c.1985	Present	Industrial Estate (including various works and builder's yards)	✓
c.1985	Present	Holmpark Industrial Estate	✓
c.1985	Present	Works	✓
c.1991	Present	Garage	✓
c.1996	Present	Sewage Pumping Station	✓

Dates		Historic Feature	Within Site
From	To		
-	-	Reid Terrace Tannery (DGC response indicates former presence, dates unconfirmed)	X

Table 2.3: Historic Development

Edition	Details
1895	Newton Stewart is shown to be well developed with key features identified including: Minnigaff Sawmills, Heugh Corn Mill (and associated mill lead), Gravel Pit, Minnigaff Corn Mill, Brewery (and associated mill lead), Gasworks and a Public Slaughter House. A clay pit is shown to the north of the site at Creebridge.
1908	A tramway is shown to the north of Minnigaff Sawmill. Cree Mills Woollen Mill (and an associated reservoir) is shown to the north of Heugh Corn Mill. The Minnigaff Corn Mill is identified as disused. A second gasholder is shown at the gasworks. No further relevant changes are shown.
1970	The brewery and both Heugh and Minnigaff Corn Mills are no longer shown. A sewage works is shown on the eastern side of the River Cree to the south of Creebridge. A telephone exchange is identified. The gasworks site has undergone development with one of the gasholders moving location. A further sewage works is shown at the south of the site on the western bank of the River Cree.
1977 – 1980	The A75 road bridge is shown to have been constructed.
1985	Commercial and industrial development is identified in the southern part of Newton Stewart with the presence of works units, a factory, and builder's yards. A tank is indicated within the footprint of Creebridge Caravan Park. Holmpark Industrial Estate is indicated at Creebridge. The sewage works is no longer shown on the eastern bank of the river. An Electrical Substation on the east bank of the River Cree. The gasworks is no longer shown.
1985 – 1989	Development at the industrial development in the south of Newton Stewart has expanded.
1995	A Sewage Pumping Station on site on the east bank of the River Cree in the location of the former electrical substation.
2005	No relevant changes are shown.

2.6.2 Potential Contamination

The Envirocheck report highlights eight areas of potentially infilled land (non-water) (ENV 59 – ENV 66). Of these, two pertain to areas within proximity of the site:

- ENV 59: This area pertains to a former gravel pit adjacent to the north of Minnigaff Corn Mill. This area is now occupied residential flats with associated shared access landscaped gardens and car parking areas; and
- ENV 66: This area pertains to a former clay pit to the north of Holmpark Industrial Estate. This area is now occupied by pavement, public open space, road surfaces and private residential properties with gardens.

There is no information available to identify the nature of any potential infill materials.

Potential sources of contamination with the potential to exist at, or within the vicinity of, the site are shown in Table 2.4 below.

Table 2.4: Characterisation of Contaminant Sources

Source Description	Description
Contaminated made ground associated with historic site use, subsequent demolition and infilling.	Heugh Mill (Corn) Minnigaff Mill (Corn) Brewery Minnigaff Sawmill Gravel Pit Mill Lade (at Minnigaff Corn Mill) Mill Lade (at Minnigaff Sawmill) Cree Mills (Woollen Mill) Sewage Works Electrical Substation
Contaminated soils associated with existing site activities.	Industrial Estate Holmpark Industrail Estate Works Garage Sewage Pumping Station
Offsite Sources	Gasworks Reid Street Tannery

2.7 Archaeological and Historical Investigations

Based on the information available from the Historic Environment Scotland Interactive Past Maps, there are 79 listed buildings identified within the Scheme area and its immediate vicinity, with numerous more identified within Newton Stewart.

Two historical monuments were recorded in the north of the Scheme area, near the confluence of the River Cree and Penkiln Burn, Minnigaff Old Church and Minnigaff, Motte Of Minnigaff Parish Church.

2.8 Consultations with Statutory Bodies and Agencies

During preparation of the ground investigation the following statutory and non-statutory bodies were consulted:

- Dumfries and Galloway Council;
- Scottish Environmental Protection Agency (SEPA);

Information from the following utility companies was also reviewed:

- Scottish & Southern Energy;
- Scottish Gas Network;
- Scottish Water; and
- British Telecommunications

2.9 Environmentally Sensitive Sites

Environmental data was recovered from the Scotland's Environment Website[1], the SEPA Website, the Envirocheck report to provide information on possible contamination issues and landfill sites, as well as information on Sites of Specific Scientific Interest (SSSI), Special Areas of Conservation (SAC), environmentally sensitive areas and heritage designations.

The following designations are recorded for the area of interest;

- The Lower River Cree SSSI extends from Newton Stewart to the estuary of the River Cree;
- Newton Stewart town centre is identified as a Conservation Area;
- The entire area is located within the South Scotland Forestry Commission Scotland (FCS) Conservancy Area; and,
- The entire area is located within the Galloway and Southern Ayrshire Biosphere Reserve.

2.10 Walkover Survey

A walkover survey was undertaken by a Sweco Geotechnical Engineer prior to the intrusive ground investigation works. Findings from the walkover were incorporated into the design of the ground investigation and informed the Geotechnical Assessment, located in the Sweco Newton Stewart FPS Desk Study Report. (January 2018).

2.11 Unexploded Ordnance (UXO)

Regional unexploded bomb risk information was obtained through Zetica Ltd., which provided an indicative UXO risk map of South West Scotland. The map is presented in **Appendix E**.

The Zetica Ltd. map details a low bomb risk for the study area and surrounding area, with a potential World War II targets located Newton Stewart.

In conclusion, the overall risk is considered low and at this stage further assessment is not considered to be required.

3 Ground Investigation

3.1 General

Based on the desk review of available ground condition information and a site walkover, an intrusive ground investigation (GI) programme was designed and undertaken to achieve the following key objectives:

- Investigate the geotechnical properties including the depth, nature and extent of any made ground and underlying drift and soil deposits;
- Investigate the geo-environmental aspects within the Scheme including potential contaminants on site.
- Provide data on each geological unit to allow geotechnical parameters to be determined for detailed design;
- Provide bedrock levels throughout the scheme to develop an understanding of the varying bedrock profile;
- Assess groundwater levels to allow an assessment of the groundwater regime in both the superficial and solid strata;
- Investigate the likely impact of geotechnical / contamination constraints identified during the preparation of the Desk Study report; and
- Investigate the condition and design of footings of existing structures in situ.

3.2 Description of Fieldwork

A detailed intrusive site investigation designed by Sweco was carried out by Holequest Limited between 13th December 2017 and 23rd January 2018, and reported in the 14th August 2018 Holequest Factual Report (Document Reference: S/NSFPS/0418/Fact. Issue 2 Final), presented in **Appendix E.**

The ground investigation techniques were selected to suit anticipated ground conditions, sampling quality and quantity requirements, depth of ground investigation required and accessibility. The site works were undertaken in accordance with BS EN 1997-1 (2004), BS EN 1997-2 (2007), BS5930 (2015) and BS EN ISO 22475-1 (2006).

The techniques used during the ground investigation together with the reasons for using them are summarised below:

- Cable Percussive Boreholes – to enable sampling and in-situ testing of superficial deposits down to bedrock level. These boreholes were also required to retrieve undisturbed, disturbed and environmental samples for geotechnical, geochemical and contamination testing, and to allow installation of gas and groundwater monitoring instrumentation within the superficial deposits;
- Rotary Open Hole Boreholes – to help advance boreholes in difficult ground conditions or where access restrictions did not allow for use of cable percussive drilling techniques. Typically progressed by "air" flush techniques, however where borehole advancement was hindered by problematic ground conditions (e.g. "blowing" sands, or elevated hydrostatic pressures) water flush was employed to enable drilling to progress
- Cored Boreholes – to enable rock samples to be recovered for examination and testing and to provide information for rock classification. These boreholes will also enable the depth and nature of the underlying bedrock to be confirmed;
- Machine Excavated Trial Pits – to enable bulk, small disturbed and environmental samples to be recovered for geotechnical, geochemical and contamination testing. These were also to facilitate inspection and in-situ testing of materials;
- Hand Excavated Trial Pits – to investigate existing structures, notably footings of existing walls, as well as allowed exposure and recording of in situ buried services.
- Borehole Installations – standpipes installed to enable gas monitoring, and groundwater sampling and monitoring.
- Standard Penetration Testing (SPT) - to determine the strength of the in-situ superficial deposits.
- Permeability Tests- to determine the groundwater profile of the Scheme.

A summary of the quantities and types of the exploratory holes undertaken during the ground investigation are summarised in **Table 3.1**.

Table 3.1: Exploratory Hole Summary

Exploratory Hole Type	Reference				Total Number	Max depth (m)
	Option 6	Option 7	Option 24	Sparling Bridge		
CP	BH2-OP6	-	-	-	1	1.35
CP + RC	BH1-OP6, BH2A-OP6 BH3-OP6 BH14-OP6	-	-	-	3	10.5
RO + RC	BH4-OP6, BH5-OP6, BH7-OP6, BH8-OP6, BH9-OP6 BH11-OP6 BH12-OP6 BH13-OP6 TP09-OP6[1]	BH1-OP7	-	BH1-SP, BH2-SP	12	19.8
TP	TP1-OP6, TP2-OP6, TP3-OP6, TP4-OP6, TP5-OP6, TP7-OP6, TP11-OP6, TP12-OP6, TP13-OP6, TP-W1-OP6, TP-W2-OP6	TP1-OP7, TP2-OP7, TP3-OP7, TP4-OP7, TP5-OP7, TP6-OP7, TP7-OP7, TP8-OP7, TP9-OP7, TP10-OP7, TP11-OP7, TP12-OP7,	TP2-OP24, TP3-OP24, TP4-OP24, TP5-OP24, TP6-OP24, TP7-OP24, TP10-OP24, TP11-OP24,	TP1-SP, TP2-SP, TP3-SP, TP4-SP, TT1-East[2], TT1-West[2]	35	3.35
HP	HP1-OP6, HP1A-OP6, HP2-OP6, HP2A-OP6, HP3-OP6, HPA-OP6, HP5-OP6, HP6-OP6, HP7-OP6, HP8-OP9, HP10-OP6, HP11-OP6, HP12-OP6, HP-SW2	HP1-OP7, HP2-OP7	-	-	16	1.85

Notes

CP: Cable Percussive Borehole

CP + RC: Cable percussive borehole with Rotary Coring follow-on, Rotary openhole may be required between drilling methods.

RO + RC: Rotary Openhole with Rotary Coring follow-on

TP: Mechanically excavated trial pit
HP: Hand excavated hand pit
1: Originally scheduled as a trial pit, TP09-OP6 was rescheduled as a borehole.
2: Trial Trench scheduled to investigate services in the Sparling Bridge proposed location.

Results obtained from the proposed Sparling Bridge site are incorporated into the summaries below in Section 3.4 as this information remains pertinent to the Scheme. Separate reporting and discussion can be found in the Holequest Ground Investigation, Newton Stewart Flood Protection Scheme, Sparling Bridge Factual Report (dated 12th April 2018) and Sweco Sparling Bridge- Foundation Design Check and Settlement Predictions (dated 11th May 2018).

All exploratory hole locations were selected by Sweco, while the as dug co-ordinates and ground levels for each position were obtained by Holequest Limited to National Grid and Ordnance Datum, respectively.

The exploratory hole locations are shown within the Holequest Factual Report in **Appendix E**.

3.3 In-situ Testing and Monitoring

The following in-situ testing was undertaken during the ground investigation works to determine the engineering and hydraulic properties of the materials encountered on site:

- 107 Standard Penetration Tests (SPT) within the cable percussive and rotary open-hole boreholes to obtain an indication of the relative density of granular soils;
- 14 permeability (falling head) tests were undertaken within selected boreholes;
- 12 standpipes were installed within selected boreholes, to allow for ground gas and groundwater monitoring.

Gas and groundwater monitoring instrumentation was installed in selected boreholes across the site to provide groundwater level and gas concentration data. Details of boreholes with gas and groundwater monitoring instrumentation, together with the monitoring results up to and including 25th April 2018 are provided in Holequest Limited's Factual Report.

3.4 Laboratory Investigation

Geotechnical and geo-environmental, contamination and rock testing was undertaken on samples of soil, rock and groundwater recovered during the December 2017 to February 2018 ground investigation works.

Laboratory testing was scheduled by Sweco. Tests were carried out by Professional Soils Laboratory Ltd, MATtest Ltd and Concept Life Sciences Ltd in accordance with BS1377:1990.

A summary of the testing undertaken is presented in **Table 3.2**, whereas all results are presented within the Holequest Factual Report which can be found in **Appendix E**.

The results of the geotechnical testing are discussed in ***Section 5*** of this report.

Table 3.2: Summary of Laboratory Testing

Testing Type	Test	No. Of Tests
Geotechnical (Soil)	Moisture Content	20
	Atterberg Limits	15
	Particle size distribution by sieving	44
	Particle size distribution by sedimentation	9
	Dry Density / moisture content relationship – 2.5kg rammer	3
	Small Shearbox	4
	One Dimensional Consolidation	4
	Undrained Triaxial	4
	Organic Matter Content	17

Testing Type	Test	No. Of Tests
Geotechnical (Rock)	Point load index	30
	Uniaxial compressive strength tests	4
Chemical	Soil Suite 1	23
	Soil Suite 2	5
	PCBs	1
	BRE SD1 Suite A	22

4 Ground Summary

This section provides the ground summary for the Scheme and provides further commentary where necessary on the available background information relating to the Scheme, which has been outlined in **Section 2**.

4.1 Geology

4.1.1 General

The ground conditions encountered during the ground investigation were generally as anticipated. Made ground and topsoil typically overlay alluvium, predominantly granular in nature with occasional cohesive units throughout. This was underlain by basal granular deposits, potentially glaciofluvial in nature. Bedrock across the Scheme was recorded as metasandstones, metasiltstones and metamudstones in concurrence with the anticipated bedrock. Glacial Till deposits were not encountered.

The geological sequence of the area is listed in **Table 4.1** with a summary of the encountered ground conditions is presented in **Table 4.2**. Details of each geological unit are described in the following sections.

Table 4.1: Summary of Soil and Rock Types

Geological Deposit / Unit	Geological Period	Depth range (m bgl)	Proven Thickness range (m)
Topsoil	Quaternary	GL-1.20	0.10-1.24
Made Ground	Quaternary	GL-4.30	0.30-4.30
Alluvial Deposits-Granular	Quaternary	0.20-13.9	0.95-13.00
Alluvial Deposits-Cohesive	Quaternary	0.30-11.60	10-4.20
Basal Granular Deposits	Quaternary	7.80-14.50	0.70-11.00
Bedrock - Gala Group	Silurian	5.10-20.00	4.50-7.10

4.1.2 Topsoil

A summary of the Topsoil distribution and characteristics is provided in **Table 4.2**.

Table 4.2: Topsoil Summary

Topsoil	
Exploratory Holes	BH2-SP, TP3-SP, TP4-SP, BH11-OP6 to BH14-OP6, TP9-OP6, TP13-OP6, BH1-OP7, TP1-OP7, TP2-OP7, TP3-OP7, TP4-OP7, TP5-OP7, TP6-OP7, TP7-OP7 TP11-OP7, TP12-OP7, TP2-OP24, TP3-OP24, TP4-OP24, TP5-OP24, TP6-OP24, TP7-OP24, TP10-OP24, TP11-OP24
Description	Topsoil was encountered across the extent of the Scheme. Generally, topsoil was described as silty sandy gravelly topsoil, locally with turf, rootlets and other organic material. Occasionally low cobble and boulder content is recorded.

4.1.3 Made Ground

A summary of the Made Ground distribution and characteristics is provided in **Table 4.3**.

Table 4.3: Made Ground Summary

Made Ground	
Exploratory Holes	BH1-OP6, BH2A-OP6, BH2-OP6, BH3-OP6, BH4-OP6, BH5-OP6, BH7-OP6, BH8-OP6, BH9-OP6, TP1-OP6, TP2-OP6, TP3-OP6, TP4-OP6, TP5-OP6, TP7-OP6, TP11-OP6, TP12-OP6, TPW1-OP6, TPW2-OP6, HP1-OP6, HP1A-OP6, HP2A-OP6, HP2-OP6, HP3-OP6, HP4-OP6, HP6-OP6, HP7-OP6, HP8-OP6, HP9-OP6, HP10-OP6, HP11-OP6, HP12-OP6, TP8-OP7, TP9-OP7, TP10-OP7, HP1-OP7, HP2-OP7, BH1-SP, TP1-SP, TP2- SP
Description	Typically made ground deposits were encountered to shallow depths, although locally deeper such as on the western bank of the River Cree at the proposed Sparling Bridge (BH8-OP6 and BH1-SP) and again on the west bank upstream (BH5-OP6). Where recorded, made ground was described predominantly as clayey, silty, sandy, gravelly topsoil in the upper stratum, often with rootlets and organic content observed. Beneath the upper layer, the composition of the made ground is highly variable, typically comprising a mixture of silty gravelly sands and sandy silty gravels. An assortment of debris was identified within the Made Ground including plastic, paper, brick, masonry, glass, coal, ash, china, lime mortar, slate, metal, bone, tile, and tarmac. Made ground was not encountered in the south of the Scheme, in particular, the Option 24 area of investigation.

4.1.4 Superficial Deposits

4.14.1 Alluvium – Granular

A summary of the granular Alluvium deposit distribution and characteristics is provided in **Table 4.4**.

Table 4.4: Alluvium – Granular Summary

Alluvium – Granular	
Exploratory Holes	BH1-OP6, BH2A-OP6, BH3-OP6, BH5-OP6, BH7-OP6, BH8-OP6, BH9-OP6, BH11-OP6, BH12-OP6, BH13-OP6, BH14-OP6, TP2-OP6, TP4-OP6, TP6-OP7, TP9-OP6, TP11-OP6, TP12-OP6, TP13-OP6, TPW1-OP6 HP12-OP6, BH1-OP7, TP3-OP7, TP4-OP7, TP5-OP7, TP7-OP7, TP9-OP7, TP10-OP7, TP11-OP7, TP12-OP7, TP2-OP24, TP3-OP24, TP4-OP24, TP5-OP24, TP6-OP24, TP7-OP24, TP10-OP24, TP11-OP24, BH1-SP, BH2-SP, TP4-SP, TP3-SP
Description	Granular deposits interpreted as Alluvium formed the bulk of the materials encountered across the Scheme, observed in all drilled boreholes. Typically, granular alluvium deposits were the first unit encountered underlying the made ground or topsoil. Granular Alluvium was encountered through a wide range of relative densities from loose through to very dense, at shallow and greater depths.

	Deposits generally comprised silty gravelly sand, typically with low cobble and boulder content and occasional clay lenses. Alongside the sand, silty sandy subangular gravel was commonly observed, often with medium to high cobble and boulder content. These deposits were typically interbedded with the cohesive alluvium deposits.

4.1.4.2 *Alluvium – Cohesive*

A summary of the cohesive Alluvium deposit distribution and characteristics is provided in **Table 4.5**.

Table 4.5: Alluvium – Cohesive Summary

Alluvium – Cohesive	
Exploratory Holes	BH1-OP6, BH4-OP6, BH7-OP6, BH9-OP6, BH11-OP6, BH12-OP6, BH13-OP6, TP1-OP6, TP4-OP6, TP7-OP6, TP9-OP6 TP1-OP7, TP2-OP7, TP10-OP7,
Description	Cohesive alluvium generally comprised sandy, silty, locally gravelly clay, with occasional lenses of organic material. Material strength varied from very soft to stiff across a range of depths and was typically recorded as smaller layers within the larger granular alluvium unit. Silt was not encountered as the primary constituent across the extent of the Scheme, although lenses were observed within the clay.

4.1.4.3 *Basal Granular Materials*

A summary of the Basal Granular Material distribution and characteristics is provided in **Table 4.6**.

Table 4.6: Basal Granular Deposit Summary

Basal Granular Deposits	
Exploratory Holes	BH4-OP6, BH5-OP6, BH8-OP6, TP9-OP6 BH1-OP7,
Description	Basal Granular deposits typically comprising medium dense to very dense silty sandy gravel with a low to high cobble and boulder content. In addition to the gravel, silty sand and sandy silt were observed within this unit. Locally, this material typically comprised very dense silty sand with minor clay lenses (BH5-OP6) and very dense slightly silty gravelly cobbles with low boulder content (BH8-OP6). Strength testing was limited within the basal granular deposits; sand as “blowing sand” conditions was encountered, particularly in BH1-OP7. The resultant differential hydrostatic head hindered the ability to perform SPTs. Where encountered, the basal granular Deposits were typically underlying the Alluvium or Glaciofluvial deposits where present. It is surmised that the basal granular deposits encountered likely comprise alluvial river terrace deposits.

4.1.5 Solid Geology

A summary of the Solid Geology distribution and characteristics is provided in **Table 4.7**.

Table 4.7: Solid Geology

Solid Geology	
Exploratory Holes	BH1-OP6, BH2A-OP6, BH3-OP6, BH4-OP6, BH5-OP6, BH7-OP6, BH8-OP6, BH9-OP6, BH11-OP6, BH12-OP6, BH13-OP6, BH14-OP6, TP9-OP6, BH1-OP7, BH1-SP, BH2-SP
Description	Bedrock recovered comprised weak to strong, often thickly bedded metasandstone interbedded with thinly laminated metamudstone and metasiltstone. This is consistent with the Gala Formation anticipated in the Scheme, in particular, the Gala Unit 1 and Gala Unit 2 wackes. Varying degrees of weathering were observed through the rock recovered, from slightly weathered to locally highly weathered. Evidence of minor faulting was observed in BH7-OP6 and BH2A-OPA. Small lenses (0.20m and 0.05m thick) of extremely weak fault rock were observed within the metasandstone bedrock, likely associated with the faulting observed trending generally parallel with the River Cree course.

4.2 Hydrogeology

4.2.1 Groundwater

Groundwater strikes were recorded within the fifty-one of the exploratory holes across the Scheme area between 0.55m bgl and a maximum recorded depth of 6.20m bgl. The majority of water strikes were recorded in the Granular Alluvium unit or at the boundary of this unit.

Within the historical ground investigation groundwater was recorded between 1.67m and 5.4m, therefore the recent ground investigation results confirm the historical findings.

Details of all groundwater strikes recorded within the Scheme are presented in **Table 4.8**.

Table 4.8: Groundwater Strike Summary

Exploratory Hole No.	Type	Water strike/ seepage (m bgl)	Level water rose to after 20min (m bgl)
BH2A-OP6	BH	4.0	-
BH3-OP6	BH	2.90	2.70
BH4-OP6	BH	4.20	-
BH5-OP6	BH	4.10	-
BH7-OP6	BH	4.10	-
BH8-OP6	BH	3.80	-
BH9-OP6	BH	3.00	-
BH11-OP6	BH	6.20	-
BH12-OP6	BH	1.30	-
BH13-OP6	BH	2.50	-
BH14-OP6	BH	2.80	1.10
BH1-OP7	BH	1.00	-

Exploratory Hole No.	Type	Water strike/ seepage (m bgl)	Level water rose to after 20min (m bgl)
BH1-SP	BH	5.80	-
BH2-SP	BH	1.80	-
TP4-OP6	TP	1.40	-
TP9-OP6	BH	2.80	-
TP11-OP6	TP	1.80	-
TP13-OP6	TP	1.50	-
TPW1-OP6	TP	0.30	-
TPW2-OP6	TP	1.00	-
TP3-OP7	TP	0.90	-
TP4-OP7	TP	0.60	-
TP5-OP7	TP	1.10	-
TP6-OP7	TP	0.95	-
TP7-OP7	TP	1.15	-
TP8-OP7	TP	1.80	-
TP9-OP7	TP	1.40	-
TP10-OP7	TP	1.20	-
TP11-OP7	TP	1.80	-
TP12-OP7	TP	0.90	-
TP2-OP24	TP	2.40	-
TP3-OP24	TP	2.10	-
TP4-OP24	TP	2.60	-
TP5-OP24	TP	1.65	-
TP6-OP24	TP	2.30	-
TP7-OP24	TP	2.40	-
TP8-OP24	TP	0.90	-
TP9-OP24	TP	1.20	-
TP11-OP24	TP	2.00	-
TP12-OP24	TP	1.00	-
TP13-OP24	TP	1.10	-
TP14-OP24	TP	1.40	-
TP3-SP	TP	1.60	-
TP4-SP	TP	1.90	-
HP1A-OP6	HP	1.60	-
HP2A-OP6	HP	0.70	-
HP3-OP6	HP	0.90	-
HP8-OP6	HP	0.55	-
HP10-OP6	HP	1.00	-

Exploratory Hole No.	Type	Water strike/ seepage (m bgl)	Level water rose to after 20min (m bgl)
HP1-OP7	HP	0.90	-
HP2-OP7	HP	1.50	-

Notes

BH: Borehole
TP: Trial Pit
HP: Hand Pit

4.2.2 Groundwater Monitoring

Groundwater monitoring was undertaken by installation of groundwater standpipes in sixteen exploratory holes. The results of groundwater monitoring are presented in **Table 4.9**.

Table 4.9: Summary of Groundwater Monitoring

Exploratory Hole No.	Groundwater monitoring depth to water (m bgl)								
	18.01.18	19.01.18	22.01.18	24.01.18	01.02.18	21.02.18	23.04.18	24.04.18	25.04.18
BH1-OP6	-	1.85	1.50	1.05	1.80	4.62	4.80	-	-
BH2A-OP6	-	-	-	-	3.60	3.63	3.80	-	-
BH3-OP6	-	-	-	-	2.60	2.83	-	2.80	-
BH4-OP6	-	-	-	-	-	1.42	-	-	-
BH5-OP6	-	-	-	-	-	-	-	2.10	-
BH7-OP6	-	1.85	1.50	1.05	1.80	2.01	2.40	-	-
BH8-OP6	-	-	-	-	-	3.80	3.90	-	-
BH9-OP6	-	-	-	-	-	3.00	3.25	-	-
BH11-OP6	-	-	-	-	-	1.59	-	-	2.10
BH12-OP6	-	-	-	-	-	2.50	-	-	3.10
BH13-OP6	-	-	-	-	-	2.00	-	-	2.20
BH14-OP6	-	-	-	-	-	2.95	-	-	1.90
TP9-OP6	-	-	-	-	-	2.05	-	-	-
BH1-OP7	-	-	-	-	0.50	0.87	-	1.10	-
BH1-SP	3.70	3.10	2.94	2.56	3.06	3.87	3.50	-	-
BH2-SP	1.26	1.25	1.07	0.54	1.30	1.55	-	1.60	-

4.3 Contaminated Land

Geochemical testing was carried out on made ground and natural soil samples recovered during the intrusive investigations. In general soil analysis was targeted at made ground, with some analysis of natural soils to assess for potential impacts form the made ground soils.

4.4 Utilities

Services were encountered in several exploratory holes during the ground investigation fieldworks. Details of the services encountered are provided in **Table 4.10**.

Table 4.10: Utilities Recorded During Ground Investigation

Exploratory Hole No.	Easting	Northing	Depth (m bgl)	Details
TP5-OP6	241245	565248	1.00	VC pipe, approx. 400mm diameter
HP6-OP6	241157	565501	0.29	Purple possible street light cable, approx. 18mm diameter

5 Laboratory Testing

5.1 General

For the purposes of this report, the ground conditions encountered are categorised as follows:

- Topsoil
- Made Ground
- Alluvial Deposits – Granular
- Alluvial Deposits – Cohesive
- Basal Granular Material
- Bedrock (Gala Formation)

This section provides a general account of the ground conditions encountered across the Scheme. The main soil and rock types encountered are summarised in **Table 5.1**, the material descriptions are included in **Section 5.2**.

The material properties and parameters for the ground conditions encountered during the ground investigation undertaken by Holequest Limited are detailed in the following sections for each stratum.

Where appropriate, tables showing a range of results, and the mean and median of results for the in-situ and laboratory testing performed on the materials are provided.

5.2 Topsoil

Table 5.1: Summary of Topsoil Testing

Test (unit of measurement)		No. of results	Results		
			Minimum	Maximum	Mean
Moisture Content (%)		1	28	-	-
Particle Size Distribution		1	-	-	-
Organic Matter Content (%)		2	1.9	6.9	4.4
BRE SD1 Suite A	pH	1	6.3	-	-
	Dissolved SO_4 (mg/l)	1	21	-	-
	Sulphur (total) (%)	1	0.05	-	-

5.3 Made Ground

Table 5.2: Summary of Made Ground Testing

Test (unit of measurement).		No. of results	Results		
			Minimum	Maximum	Mean
Moisture Content (%)		4	15	28	21.5
Atterberg Limits	Liquid Limit	2	35	44	39.5
	Plastic Limit	2	22	24	23
	Plasticity Index	2	13	20	16.5
Particle Size Distribution		9	-	-	-
Organic Matter Content (%)		3	2.4	13	9

BRE SD1 Suite A	pH	15	5.9	11.8	7.76
	Dissolved SO_4 (mg/l)	15	<10	100	28
	Sulphur (total) (%)	15	0.01	0.52	0.11
SPT N Value (Uncorrected)		9	10	50	32

5.4 Alluvial Deposits

Table 5.3: Summary of Granular Alluvium Testing

Test (unit of measurement).		**No. of results**	**Results**		
			Minimum	**Maximum**	**Mean**
Moisture Content (%)		4	5.6	23	16.4
Atterberg Limits	Liquid Limit	1	32	-	-
	Plastic Limit	3	non plastic	22	-
	Plasticity Index	1	10	-	-
Particle Size Distribution		25	-	-	-
Maximum Dry Density (Mg/m^3)		3	1.8	2.04	1.93
Optimum Moisture Content (%)		3	10	13	12
Shear Box	Angle of Shearing Resistance (°)	4	36	38	37
	Effective Cohesion (kPa)	4	4	13	8.25
Organic Matter Content (%)		11	0.5	5	2.1
BRE SD1 Suite A	pH	5	5.9	7	6.4
	Dissolved SO_4 (mg/l)	5	<10	51	<10
	Sulphur (total) (%)	5	0.02	0.19	0.07
SPT N Value (Uncorrected)		75	6	50	40

Table 5.4: Summary of Cohesive Alluvium Testing

Test (unit of measurement).		No. of results	Results		
			Minimum	Maximum	Mean
Moisture Content (%)		10	5.1	43	27
Atterberg Limits	Liquid Limit	6	43	84	64
	Plastic Limit	9	non plastic	37	29
	Plasticity Index	6	22	47	36
Particle Size Distribution		8	-	-	-
Undrained Shear Strength Triaxial Compression (kPa)		4	13	39	24.75
One Dimensional Consolidation	Coefficient of volume compressibility m_v (m^2/MN)	4	0.13	1.45	0.55
	Coefficient of consolidation c_v (m^2/yr)	4	0.19	2.04	1.35
Organic Matter Content (%)		1	4.6	-	-
BRE SD1 Suite A	pH	1	6.9	-	-
	Dissolved SO_4 (mg/l)	1	<10	-	-
	Sulphur (total) (%)	1	0.03	-	-
SPT N Value (Uncorrected)		5	7	46	20

5.5 Basal Granular Material

Minimal testing was performed in Basal Granular Material due to the limited occurrence and sampling of this unit.

Table 5.5: Summary of Basal Granular Material Testing

Test (unit of measurement)	No. of results	Results		
		Minimum	Maximum	Mean
Moisture Content (%)	1	20	-	-
Particle Size Distribution	1	-	-	-
SPT N Value (Uncorrected)	7	41	50	48

5.6 Bedrock

Bedrock comprising metasandstone, metasiltstone and metamudstone was encountered across the Scheme.

A summary of the material properties for the metamorphic strata is presented in **Table 5.6**.

Table 5.6: Summary of rock testing results for metamorphic bedrock

Exploratory Hole No.	Test (unit of measurement)	No. of Tests	Results		
			Minimum	Maximum	Mean
BH8-OP6, BH11-OP6, BH13-OP6, BH1-OP7	Moisture Content (%)	4	0.2	0.5	0.35
	Bulk Density (Mg/m^3)	4	2.64	2.69	2.67
	Dry Density (Mg/m^3)	4	2.63	2.68	2.66
BH1-OP6, BH3-OP6, BH8-OP6, BH11-OP6, BH13-OP6, BH1-OP7	Point Load Index $Is_{(50)}$ Axial (MPa)	60	0.63	6.59	3.23
	Point Load Index $Is_{(50)}$ Diametral (MPa)	30	0.20	7.91	2.86
BH8-OP6, BH11-OP6, BH13-OP6, BH1-OP7	Uniaxial Compressive Strength (MPa)	4	22.2	47.1	31.85

5.7 Standard Penetration Test (SPT)

SPTs were carried out within the cable percussive and rotary boreholes, where possible, at approximately 1.5m centres, to provide an indication of soil consistency and strength. Obtained SPT N values have been presented in **Figure 5.1**. It should be noted that all SPT N values presented in this report are uncorrected values and any values that exceed an N value of 50 have been capped at the N value of 50, This includes all N values reported >50.

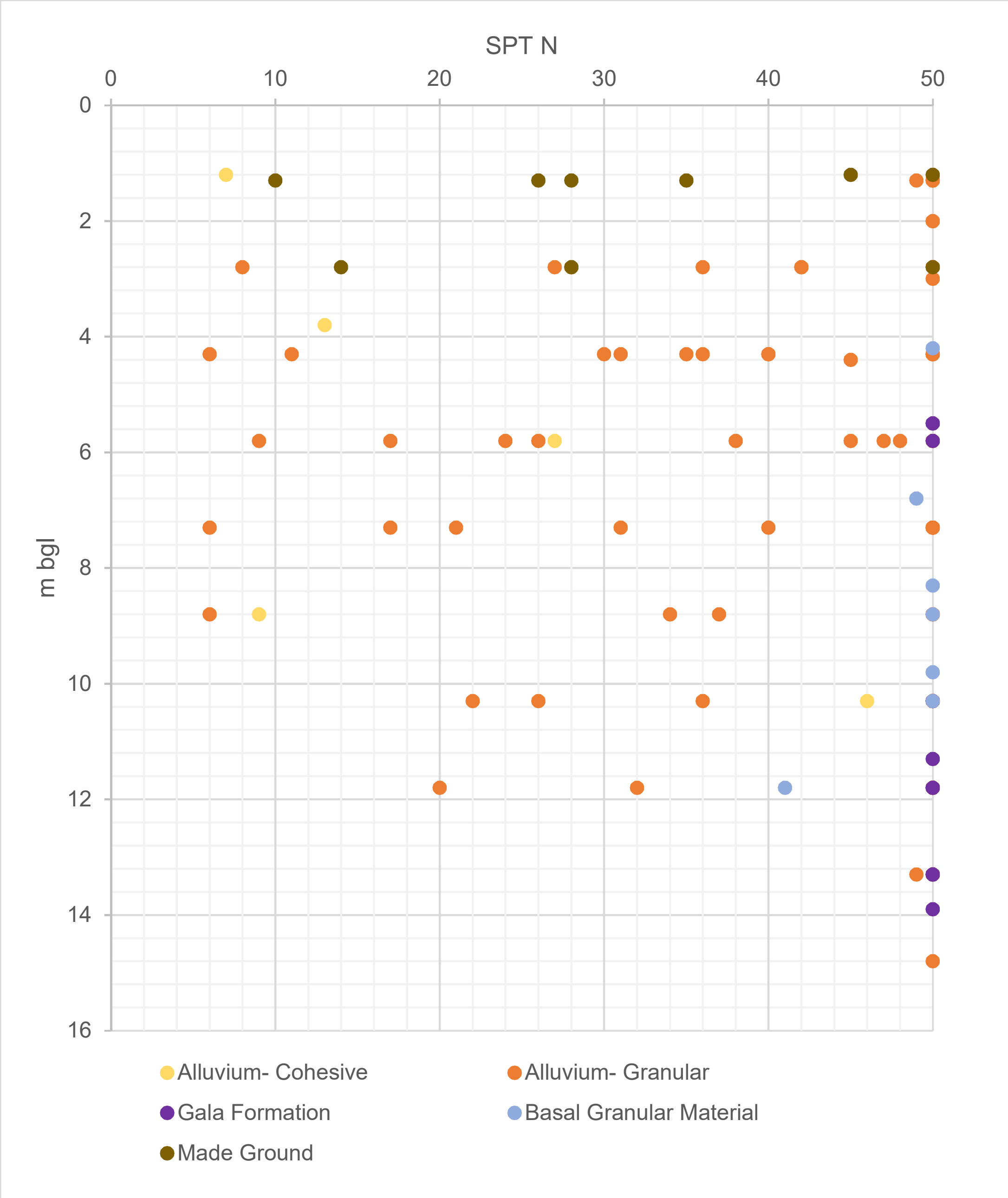

Figure 5.1: SPT N values vs depth for all encountered materials.

5.8 BRE SD1 - Ground Aggressivity Testing

To assess the aggressivity of the ground to buried concrete, the soil samples were assessed against values outlined in BRE Special Digest 1: 2005 Concrete in aggressive ground. This comprises testing for values of pH, Aqueous Sulphate, Ammoniacal Nitrogen, Nitrate, Total Sulphur, Aqueous Magnesium and Total Sulphate as SO_4. The Design Sulphate (DS) class and Aggressive Chemical Environment for Concrete (ACEC) class derived from testing results are summarised in **Table 5.7**.

Table 5.7: Summary of DC & ACEC Classifications

Exploratory Hole No.	Depth (m)	Aqueous SO_4 (mg/l)	pH	DS	ACEC
BH1-OP6	0.5	<10	7.1	DS-1	AC-1
BH4-OP6	0.5	11	7.8	DS-1	AC-1
BH5-OP6	0.2	100	11.8	DS-1	AC-1
BH7-OP6	1	17	8.1	DS-1	AC-1
BH8-OP6	0.5	<10	7.2	DS-1	AC-1
BH11-OP6	0.9	51	6	DS-1	AC-1
BH12-OP6	0.2	<10	6.8	DS-1	AC-1
BH1-OP7	1.3	<10	7	DS-1	AC-1
TP2-OP6	0.4	<10	7.9	DS-1	AC-1
TP7-OP6	0.7	<10	6.9	DS-1	AC-1
TP9-OP6	0.5	21	6.3	DS-1	AC-1
TP12-OP7	0.6	<10	6.6	DS-1	AC-1
TP1-SP	0.5	13	8	DS-1	AC-1
TP2-SP	0.5	15	8.3	DS-1	AC-1
TP3-SP	0.7	<10	6.2	DS-1	AC-1
TP4-SP	0.5	<10	5.9	DS-1	AC-1
HP1-OP6	0.2	<10	8.4	DS-1	AC-1
HP2-OP7	1	<10	7.8	DS-1	AC-1
HP8-OP6	0.2	38	7.7	DS-1	AC-1
HP10-OP6	0.2	<10	5.9	DS-1	AC-1
HP11-OP6	0.2	30	7.4	DS-1	AC-1
HP12-OP6	0.2	11	6.4	DS-1	AC-1

With regards to ground aggressivity to buried concrete, in view of the findings of the laboratory testing, and in line with the recommendations BRE Special Digest, a DS and ACEC class of DS-1 and AC-1 would be appropriate for the design of buried services.

5.9 Geo-environmental analysis

5.9.1 Assessment Approach

Following a review of applicable guideline values for concentrations of potential contaminants in soil that are protective of Human Health, Sweco has identified appropriate Assessment Criteria for the initial Tier 1 review of contaminant concentrations within site soils as follows,

Suitable for Use Levels (S4UL) 2015: In January 2015 LQM/CIEH published Suitable for Use Levels (S4ULs) for a total of 89 chemicals or groups of chemicals which represent a minimal level of risk (equivalent to risk levels used in the derivation of SGVs). These were generated using the updated scenarios found in the UK government's C4SL framework, revisions to chemical data and updated toxicological data. where available, and generated using the CLEA software (v1.06). Transparent explanation of the S4UL generation process including all chemical input parameters is provided within the LQM Report.

5.9.2 Summary of Initial Tier 1 Screening

Screening criteria have been applied for a Public Open Space (Parks) land use scenario. The average Soil Organic Matter content for the analysed samples is 6.06% and therefore Tier 1 screening criteria are based upon SOM content of 6%.

A total of 22 no. soil samples were screened against the appropriate criteria as presented in ***Appendix D***. Exceedances of screening criteria are summarised in ***Table 5.8***.

Table 5.8 – Summary of Tier 1 Soil Screening Assessment

Analyte	Screening Value (mg/kg)	No. of Analysis / Area	Exceedance Range (mg/kg)	Exceedances	
				No.	%
Town Centre – Option 6 Area					
Lead	1,300	12	1,400 – 1,900	3	25
Sparling Bridge					
Benzo(a)pyrene	13	3	14	1	33
Dibenzo(ah)anthracene	1.4	3	1.9	1	33
Benzo(b)flouranthene	16	3	17	1	33

5.9.3 Asbestos Identification Assessment

Asbestos identification testing was completed for 22 soil samples. Asbestos was identified to be present in 1 of the samples tested (representing approximately 5% of the samples tested). A summary of the analytical screening is provided in ***Table 5.9***.

*Table 5.9 **–** Summary of Asbestos Analysis*

BH / TP No.	Depth (mbgl)	Asbestos Type	Quantification (%)
Sparling Bridge			
SP-TP1	0.5	Amosite	<0.001

5.9.4 Assessment of Risk to Human Health from Soils

Elevated concentrations of PAH compounds have been identified in one soil sample recovered from the Sparling Bridge area of the site (SP-TP1) which was taken from Made Ground. No observed source of PAH was noted in the Trial Pit log. Although concentrations have been identified to be above their respective GAC, they are only marginally in excess of their respective GAC therefore it is unlikely that these soils, if left in situ, will to pose a risk to future site users in the context of public open space end use.

Risks associated with the presence of asbestos relate predominantly to respirable fibre release. Asbestos impact has been recorded in one soil sample taken from the Sparling Bridge area of the site (SP-TP2) at a depth of 0.5m bgl. Quantification of the asbestos has shown asbestos to be present at <0.001%. Although a very low quantity of asbestos has been recorded, asbestos is present in shallow soils and therefore there is the potential for exposure to site users and site workers during ground disturbance works

6 Geotechnical Assessment

6.1 General

6.1.1 Nature of Development

The development proposals are anticipated to comprise a combination of the modification of existing walls, the construction of new embankments and walls, and the re-profiling of the river channel. Modification of existing walls will involve the provision of a glass wall flood barrier on top of the existing flood wall. New walls will consist of cast in-situ concrete walls with brick facing with or without a glass wall flood barrier.

New embankments will be constructed with a low permeability soil and include a low permeability barrier in the core. Reprofiling of the existing channel of the River Cree will be undertaken to provide increased flood flow capacity.

At the time of writing, drawings 118908-SWECO-SK126 Rev0 and 118908-SWECO-SK127 Rev0 presented in **Appendix A** indicate the layout of the proposed flood defences.

While the exact structural loadings are unknown at this point, it is anticipated that the maximum loading on the ground from the structures will not exceed 50-75kN/m^2.

6.1.2 Ground Conditions

Topsoil was encountered across the extent of the Scheme to a maximum depth of 1.2m. It comprised silty sandy gravelly topsoil, locally with turf, rootlets and other organic material.

Made ground was encountered to typically shallow depth, although locally deeper on the western banks of the River Cree at the proposed Sparling Bridge and again on the west bank upstream (BH5-OP6) to a maximum depth of 4.3m. Made ground was described as predominantly clayey silty sandy gravelly topsoil in the upper stratum. The underlying made ground was highly variable typically comprising silty gravelly sands and sandy silty gravels. Made ground included occasional plastic, paper, brick, masonry, glass, coal, ash, china, and lime mortar. Made ground was not encountered in the south of the Scheme, in the Option 24 area east of the River Cree.

Granular alluvium was the predominant natural superficial stratum encountered across the scheme, with relative densities from loose through to very dense (typically dense). Cohesive alluvium was less prevalent, and generally comprised sandy, silty, locally gravelly clay with occasional lenses of organic material. The cohesive deposits ranged from soft to stiff in consistency across a range of depths and was typically recorded as smaller layers within the larger granular alluvium unit.

Basal Granular deposits typically comprised medium dense to very dense silty sandy gravel with a low to high cobble and boulder content. These deposits likely represent a unit alluvial river terrace deposits.

Bedrock was encountered at depths of 5.1-20m BGL, and proven through rotary core drilling from 4.5 to 7.1 m. Bedrock was weak to strong, often thickly bedded metasandstone interbedded with thinly laminated metamudstone and metasiltstone (Gala Formation). This had varying degrees of weathering, from slightly weathered to locally highly weathered. Evidence of minor faulting was observed in BH7-OP6 and BH2-OPA.

6.2 Earthworks

The most significant earthworks are associated with the re-profiling of the banks of the River Cree, mostly downstream of Sparling Bridge. Based on the available logs, this will necessitate the excavation and removal of granular alluvium, Made Ground and limited cohesive alluvium, in order of anticipated volumes (highest first).

Earthworks associated with the proposed embankments located on the east bank upstream from the pumping station, and on the west bank upstream from the B7079 bridge adjacent Police Scotland buildings, will be required.

6.3 Excavations

Excavation works will predominantly comprise the excavation of made ground and natural superficial materials from within the direct vicinity of any proposed foundations for new flood walls, including the wall upstream of the Sparling Bridge on the west bank, and, downstream of the weir/ B7079 bridge on the east bank.

Excavations will also be required on the west bank of the River Cree between Sparling Bridge and the A75 bridge, and, on the east bank upstream and downstream of Sparling Bridge, for the proposed River Cree channel re-profiling. On the west bank the material to be excavated includes Made Ground (BH8-OP6: GL – 3.8m), Alluvium (cohesive) (BH09–OP6: GL – 2.2m), with the potential for other soil types. On the east bank the material to be excavated will include Alluvium (granular) (BH2-SP: 0.6-9.9m), also with the potential for other soil types particularly due to the limited GI in this area.

The location of any buried services should be identified as part of the site development planning activities and may require specific excavation to enable any requisite replacement or rerouting prior to commencement of construction.

6.3.1 Groundwater in Excavations

During ground investigation works, groundwater was encountered initially in all boreholes with initial depth ranging 0.5-3.7mbgl. The results of the groundwater monitoring showed water levels at depths between 0.54 and 4.62mbgl. Note that the groundwater regime may not have been fully revealed by the fieldwork and monitoring, and seasonal variations may occur, particularly associated with elevated river levels.

Depending on the required depths of excavations, groundwater may be encountered. Close to the river, the water level is expected to be reasonably consistent with river water levels. Therefore, appropriate groundwater control measures should be adopted during excavations. This may, depending on the nature of the strata, require sump/ pump techniques, particularly where deeper excavations in granular strata are undertaken.

6.3.2 Stability of Excavations

Instability, especially as evidenced by the collapse of trial pit sides, was noted in most of the trial pits. Temporary support is to be required for the construction of new walls since there appears to be insufficient space to batter excavation slopes back to appropriate angles. These temporary works are likely to comprise use of trench boxes and possibly propped or cantilevered sheet piles.

6.4 Earthworks Re-use of site won materials

The following appraisal is of a general nature and considers materials and testing from exploratory holes across the site.

6.4.1 General

An initial review of material re-use has been undertaken using the specification for Highway Works (SHW) acceptance criteria. Such criteria indicate the potential that exists to excavate, transport, deposit and compact materials for use as general highway fills. Enhanced criteria would apply should the fill require to carry foundation loads and lesser criteria may apply to landscape areas. Appropriate acceptance criteria would need to be derived for earthworks materials depending on the nature of the surface development proposals.

Natural soil excavated within the area of the proposed river channel re-profiling during ground investigations was predominantly described as granular alluvium (SAND and GRAVEL, typically slightly silty with low cobble content) with localised granular made ground. The granular material may comply with the grading characteristics of SHW Class 1 (General Granular Fill) and Class 6 (Selected Granular Fill) material; pending processing to achieve acceptable grading, and achieving other acceptability criteria.

The material reclaimed from the river re-profiling is likely to be moist or wet on excavation, and as such may require drying prior to usage. It is envisaged that appropriately controlled stockpiling of granular materials would allow the draining and drying of such materials, thus achieving requisite moisture contents for re use.

Minimal incidence of cohesive materials was recorded in the area of river channel reprofiling; alluvial clays were recorded a limited number of intrusive positions and were not extensive. The cohesive material may not be therefore be sufficient within the reprofiling section to be considered for re-use. Consideration should therefore be made, in the likely absence of an appropriate source, for importation of cohesive materials for use within the scheme (such as forming cores to embankments).

If clay materials are to be re-used, such materials will be moisture sensitive, and if notably wet on excavation may not be easy to dry sufficiently to enable reuse. Such marginal materials may not improve except perhaps with the addition of lime to render the materials acceptable for re-use as Class 2 general earthworks fills. It is therefore expected that these will only be suitable for use as non-structural landscape fills, dependent on the acceptability criteria applied.

It should be noted that if the softer alluvial deposits at the sites are encountered in open excavations they may be difficult to work and traffic, and appropriate control measures should be adopted to inhibit generation and migration of fines during the works.

6.4.2 Other considerations

The use of site won materials for landscaping will also need to consider the chemical and engineering properties of the materials.

6.5 Foundations

6.5.1 General

The proposed flood walls include the

- modification of existing walls by installing a glass wall flood barrier on top of the existing wall
- construction of new walls,
- construction of new walls with glass wall flood barrier.

This installation of a glass wall flood barrier on top of the existing is unlikely to significantly increase foundation loadings. Therefore, providing structural integrity of existing footings and walls, no foundation alterations are expected (subject to confirmation of structural checks taking considerations of wind loads, flood loads, etc). It is anticipated that the proposed flood wall loadings will be in the region of 50-75kN/m2.

The construction of new wall will require the construction of footings, anticipated to be conventional spread footings. In general, foundations for new walls should be formed on natural strata (granular alluvium) with made ground deposits typically considered unsuitable as a formation stratum due to the potential for variable geotechnical characteristics.

It is recommended that all foundation formations should be subject to standard site procedures including the inspection of formation by an appropriately experienced geotechnical engineer, and the removal of any unsuitable made ground, hard spots, and any soft, loose or organic materials, or the like.

Locally, deeper made ground deposits were encountered, notably upstream of the Sparling Bridge on the west bank of the Cree, and on the east bank downstream of the Cree bridge. New walls are proposed at these locations, and consequently deeper excavations may be required to remove unsuitable (made ground) materials expected to be present. It is noted, however, that the made ground in these locations comprises reworked natural alluvial deposits, with geotechnical testing indicating the materials to be medium dense in situ. It is considered that an appropriate inspection and in situ testing regime may possibly permit foundations to be placed on these materials.

6.5.2 Summary

There is a requirement for new foundations as part of the proposed flood protection works. The ground investigations indicate the anticipated founding strata (granular alluvium) to be of medium density, or greater, with suitable bearing capacity achieved at shallow (circa 1.0m to 1.5m depths). However, due to the variable nature of the superficial deposits encountered, founding depths and formation strata may vary locally, and therefore a systematic and managed regime of inspection and in situ testing should be implemented to confirm the suitability of the founding strata in situ.

7 Conclusions and Recommendations

7.1 General

The aim of this report was to provide guidance on the design and construction of the foundations, earthworks and infrastructures associated with Newton Stewart Flood Protection Scheme.

The conclusions and recommendations provided below are given as guidance to advance the Scheme.

7.2 Foundations

In line with construction design, ground conditions in this report will require to be verified during construction with appropriate in situ testing and visual inspections.

The proposed new flood wall defences are anticipated to be largely founded on granular alluvial strata. Locally, where deeper made ground deposits are present, it is considered that an appropriate inspection and in situ testing regime may possibly permit foundations to be placed on these materials.

Temporary works may be required to form excavations, including the use of trench boxes and/ or sheet piling.

Confirmatory testing shall be required to ensure the formation stratum provides the appropriate bearing capacity.

It is noted that locally deep (at least 4.30m bgl) excavation may be required to achieve suitable founding stratum or to achieve consistent conditions across the foundation should the made ground in situ prove an unsuitable stratum upon which to place foundations.

Appropriate groundwater controls within excavations will be required, due to the proximity of the works to the watercourses, and the presence of shallow groundwater levels locally.

7.3 Earthworks / Re-use

An initial review of material re use has been undertaken from the Specification for Highway Works (SHW) acceptance criteria. Such criteria indicate the potential that exists to excavate, transport, deposit and compact materials for use as general fills; these criteria have been applied to use in flood embankments. Lesser criteria may apply to landscaping fills.

Appropriate acceptance criteria would need to be derived for earthworks materials, and the geotechnical and chemical (contamination) characteristics of any excavated materials will need to be considered prior to re-use on site or off-site disposal.

For the most part, topsoil will be stripped prior to the start of construction and stored in stockpiles ready for re use on the completed earthworks slopes. Made ground encountered within the Scheme would need to be screened for deleterious or putrescible materials before reuse.

Superficials encountered on site comprised predominantly granular alluvium, which could potentially be re used as SHW Class 1 general fill, subject to confirmatory testing (i.e. moisture content, PSD, MCV tests), and the separation of cohesive materials when encountered. Indeed, Options 7 and 24 are anticipated to involve the excavation of significant volumes of alluvium from the bank River Cree. Site won compacted granular fill may be appropriate for use in embankment construction.

It is unlikely that targeted excavation of cohesive soils for use as SHW Class 2 fill would be productive given the sparsity of cohesive materials in the Scheme.

It is anticipated that the majority of topsoil in the Scheme will be suitable for Class 4 Landscape Fill for dressing on embankments.

It is recommended that any imported material required for construction purposes is subject to chemical analysis and assessed against relevant screening values to demonstrate its chemical suitability for use.

7.4 Concrete and Ground Aggressivity

BRE Ground Aggressivity testing, in accordance with the recommendations of BRE Special Digest 1: 2005, indicated a DS of DS-1 and ACEC of AC-1 should be used for the design of buried structures.

Made ground and organic materials should be removed from proximity of buried concrete.

7.5 Environmental Ground Investigation

A total of 22 soils samples of Made Ground and natural strata were submitted for geochemical analysis from a spread of locations across the site.

Marginally elevated concentrations of Lead and individual PAHs were recorded on site, and one incidence of Asbestos being identified.

In general, the materials encountered are present within locations that do not pose a risk to human health. However, if they were to be reused in areas which may allow contact with human health receptors (such as at ground surface) then further risk assessment would be required.

Lead

Lead was recorded in three soil samples taken from Made Ground in the town centre / Option 6 area of the site. 2 samples were from beneath the Cree Bridge roadway, and 1 sample from the river bank to the south of the Cree Bridge. Given the marginal exceedances and the location of materials beneath hardstanding in 2 samples, and an inaccessible area for the other samples, it is considered that there is a very low risk to human health from lead. Site workers should be made aware of risks associated with working in lead impacted soils.

PAHs

PAHs were in one soil sample taken from shallow Made Ground in the Sparling Bridge area, however the marginal nature of the exceedances combined with the absence of an observed source of PAH in the trial pit logs indicates that there is only a very low risk to human health. It should be noted that this area is in close proximity to a former gasworks which has previous been remediated, therefore based on the presence of elevated PAHs, intrusive works in this area should be closely observed for further signs of contamination. If contamination is observed then works should be stopped and advice sought from an environmental consultant.

Asbestos

Amosite asbestos fibres were detected in one soil sample taken from shallow made ground in the Sparling Bridge area. Although a very low quantity of asbestos was recorded, asbestos is present in shallow soil in this area and there is therefore the potential for exposure to site users and site workers during ground disturbance works. This information should be communicated to the contractor and should be included in the asbestos register for the site.

<u>Potential for Unforeseen Contamination</u>

In the unlikely event of any sign of unexpected contamination be identified during earthworks or construction (e.g. hydrocarbon impacted soils, asbestos etc.), work in such area should be temporarily halted until a suitably qualified professional has been consulted to assess the situation and provide advice.

Similarly, vigilance should be maintained for any unexpected areas of made ground.

Appendix A: Plans

Appendix B: Envirocheck Report

Appendix C: Historical Ground Investigations

Appendix D: Unexploded Ordnance (UXO) Report

Appendix E: Holequest Ground Investigation Factual Report