REPLICATE	Project no. 691735 REPLICATE PROJECT Renaissance of Places with Innovative Citizenship And Technology	This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

REPLICATE PROJECT

REnaissance of PLaces with Innovative Citizenship And Technology

Project no. 691735

H2020-SCC-2015 Smart Cities and Communities

Innovation Action (IA)

D5.2 Connection of a 13 block (700 flats) district heating network to a gas CHP energy centre

Due date of deliverable: 31/07/2019

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Organisation name of lead contractor for this deliverable: Bristol

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Editor/Lead beneficiary :	BRISTOL CITY COUNCIL
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1. EXECUTIVE SUMMARY

The Purpose of the Bristol Pilot District Heating Project is to provide a lower carbon and more efficient heat to the existing and new District heating systems by linking together the operational Heat Network connecting 13 social housing blocks with a new network that will be powered by a Combined Heat and Power Engine. Each system has peak and reserve back up gas boilers but by linking the two energy centres the whole system will better utilise the low carbon heat from the Biomass and the CHP providing more efficient and cheaper heat across the network. The project also includes upgrades to existing and the addition of new metering and control units on the existing network in order to ready the old equipment to be integrated into a smart network in the future.

The document below describes the work that has been delivered including the technical aspects of the installed equipment and standards that Bristol Pilot is working to. This includes the procurement process and lessons learnt from this, the contractual arrangements and how these changed as part of the procurement learning. The construction phase of the project is described and shows how the correct contracting method can support good collaborative working practices between client and contractor leading to an increase of quality on the project while also controlling costs.

During the project several changes in scope were made in order to introduce innovation in testing procedures to increase the quality and Quality Assurance (QA) processes.

The project has produce methodology in contracting, QA process and a suite of documents that can all be replicated and scaled up for the future build out of Bristol's heat network.

This project will be of interest to those wishing to build a heat network in a busy city centre environment while being constrained by public procurement regulations. It shows how by working collaboratively with a strong project team quality can be increased in construction that supports a long term asset in operation

2. REPLICATE

The main objective of REPLICATE project is the development and validation in three lighthouse cities (**San Sebastián** - Spain, **Florence** - Italy and **Bristol** - UK) of a comprehensive and sustainable City Business Model to enhance the transition process to a smart city in the areas of the energy efficiency, sustainable mobility and ICT/Infrastructure. This will accelerate the deployment of innovative technologies, organizational and economic solutions to significantly increase resource and energy efficiency improve the sustainability of urban transport and drastically reduce greenhouse gas emissions in urban areas.

REPLICATE project aims to increase the quality of life for citizens across Europe by demonstrating the impact of innovative technologies used to co-create smart city services with citizens, and prove the optimal process for replicating successes within cities and across cities.

The Business Models that are being tested through large scale demonstrators at the three cities are approached with an integrated planning through a co-productive vision, involving citizens and cities' stakeholders, providing integrated viable solutions to existing challenges in urban areas and to procure sustainable services. Sustainability of the solutions is fostered in three areas: economic and environmental and finally, fostering transparency in the public management.

In addition, the Model features the replicability of the solutions and their scale up in the entire city and in follower cities, particularly in three follower cities (**Essen** - Germany, **Laussane** - Switzerland and **Nilüfer**-Turkey) that are involved in the project and therefore, have access to know-how and results achieved on the project so they can apply the developed model. At the moment, there are 2 observer cities, Guanzhou (China) and Bogota (Colombia).

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3. INTRODUCTION

3.1 Relation to Other Project Documents

The district heating element of Bristol's REPLICATE programme is linked to the energy measures (ST 5.1), Smart Homes and RETROFIT as they all aim to reduce CO2 and costs for Citizens. The district heating project will also endeavour to link into the Energy Demand Management System (ST 5.1.3) as part of the Energy Demand trails and the data created from the system will go to the Smart City Platform

3.2 Reference documents

This document is based in the following projects level documents:

Ref.	Title	Description
REPLICATE Grant Agreement signed 240713.pdf	Grant Agreement	Grant Agreement no. 691735
DoA REPLICATE (691735)	REPLICATE Annex 1 – DoA to the GA	Description of the Action
REPLICATE Consortium agreement signed December 2015 (7th December version)	Consortium Agreement	REPLICATE project – Consortium Agreement
REPLICATE Project Management Plan	D1.1 Project Management Plan (v.1) (29/04/2016)	REPLICATE Project Management Plan
REPLICATE District Management Plans	D1.6 District Management Plan Bristol	REPLICATE District Management Plans
REPLICATE Communication Plan	D11.1 Communication Plan	REPLICATE Communication Plan

Where there are contradictions, the documents listed above supersede this deliverable. The Grant Agreement is the contract with the European Commission so takes precedence over all other documents.

3.3 Abbreviations list

GA	Grant Agreement
CA	Consortium Agreement
DoA	Annex I–Description of the Action
EC	European Commission
H2020	Horizon 2020
PC	Project Coordinator
PL	Pilot Leader
PMP	Project Management Plan
TC	Technical Coordinator
WP	Work Package
WPL	Work Package Leader

4. DELIVERABLE DESCRIPTION

The projects technical details and processes though from the procurement stage to end of construction at the end of July 2019 are described under the present document which covers:

- **Section 5**: Introduction. This section includes a general description of the works to be undertaken and over view of the project
- **Section 6**: Activities, describes the activities undertaken that were funded by the REPLICATE project
- **Section 7**: Procurement Phase. This section describes the procurement journey, including consultants and support staff and coordination of this project to ongoing works in the area.
- **Section 8**: Technical Information. This section describes the technical information regarding the different sections of the project and any equipment that is relevant to each one.
- **Section 9**: Construction Phase describes the contracting and construction element concentrating on the main pipework that was the key part of the project
- **Section 10**: Controls Strategy – Explains the rationale of the controls strategy and illustrates the topography of the data system
- **Section 11**: describes how the data will be collected and monitored
- **Section 12**: Lessons learnt are illustrated from across the project from design, procurement, contracting and construction.
- **Section 13**: Innovation, Impacts and Scalability includes how the project has enabled Bristol to innovate and prepare for a larger build out of District heating systems across the city as well as raise standards in the industry.
- **Section 14**: Main conclusions are described.

5. INTRODUCTION

5.1 GENERAL DESCRIPTION

The Bristol Pilot has connected the existing system deployed in known as the Redcliffe Network (at Broughton House Energy Centre) to the Council's offices in 100 Temple Street where a new energy centre is being constructed (purple the map below). So there will be two larger heat networks connected which in themselves will have multiple connections (i.e. 13 social housing blocks, offices hotels and private housing).

It is estimated that the Redcliffe heat network will provide 17,235Mwh of energy across the scheme once all connections are complete but this will be post the REPLICATE timeline.

The amount of energy that is supplied to the connection that is estimated to be delivered within the Replicate timescale is estimated at 14,611 MWh of energy.

In terms of the people affected by the scheme the estimation is that there will be 11,000 people benefiting from the building connections to the Heat Network

The impact in terms of CO2 for the original DH proposal with the biomass boiler and the new solution proposed is estimated at 5200 tonnes / year.

For these figures to be realised there are a lot of external influences and contractual agreements yet to be reached.

The new energy centre at 100 Temple Street will be primarily powered by a gas CHP plant which would provide low cost heat to the new developments exiting buildings within the locality. The existing social housing heat network in Redcliffe is composed of residential properties and the Temple Street system will be predominantly commercial and office use. Connecting Broughton House Energy Centre with 100 Temple Street's proposed gas CHP would provide efficiencies, improve fuel flexibility and reduce the loading strains on both systems. This would be achieved through smart controls of each energy centre, allowing balancing between each plant to ensure energy demands are intrinsically linked to energy generation – ensuring both boilers and CHPs are operated at optimum peak loading

5.2 TECHNOLOGICAL INFORMATION

The installation of a network extension between the biomass boilers at Broughton House in the Redcliffe network to 100 Temple Street will save up to 255 tonnes of CO2, without considering future connections.

This will be because the system will be able to utilise the Biomass boiler more effectively as well as displacing standard gas boilers with the more efficient CHP engine on the network.

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Bristol City Council (BCC) installed a 150DN pipe with associated cabling and controls within the Broughton House energy centre at a cost of 1.4m euros that will allow the heat network to grow further to connect to other nearby buildings. The project will enable Bristol to develop the connections to the wider energy demand management work (the energy demand management system) in the district including where applicable ICT architecture designs and possible systems integrations.

The initial connection supplying heat to 100 Temple Street will be 100% renewably fuelled from the existing 1MWth wood pellet boiler. As additional buildings are connected via additional pipe branches from the main REPLICATE-funded pipe (see map 2), they are likely to be heated by a gas CHP from a proposed installation in 100 Temple St. These additional pipe branches are facilitated by the REPLICATE connection to 100 Temple Street, but would be funded through a combination of heat sales and developer contributions. Where economically viable, the CHP fuel input will be biogas – regular reviews to ensure heat customers are not overcharged will be required for this.

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6. ACTIVITIES – WORKS RATIONALE AND FIT

6.1 The activities to be developed under work package Sub Task 5.1.2 District Heating in Bristol have been the following:

- Procurement
- Works and services will be procured for the connection between an energy centre in Temple Street and a separate nearby district heating system in Redcliffe (Broughton House).
- Construction and implementation of the connection to a district heating system and an energy centre utilizing a future CHP
- The construction of the connection to a district heating system containing 700 apartments in 13 social housing blocks will include the deployment of piping, infrastructure and a control system to allow economies of scale in heat generation as well as enabling future connections of new developments to the district heating network.
- The activities include legal advice and procurement and technical support during planning and implementation.
- It will also be linked to the trial energy demand side management system where strategy feasibility and design has been completed.
- REPLICATE will fund the non-asset costs to this implementation including the design, roadworks and project management duties required.

6.2 Impacts

The new scheme provides 17,235Mwh of energy across the scheme once all connections are complete. The amount of energy that is supplied to the connection that is certain to be delivered within the Replicate timescale is estimated at 14,611 MWh of energy supplied.

Additionally there will be an additional 4332Mwh of energy supplied per year post Replicate.

Scheme the estimation there will be 11,000 people benefiting from the building connections to the Heat Network within the replicate timescale and an additional 3500 benefiting post Replicate.

The impact in terms of CO2 for the original DH proposal with the biomass boiler and the new solution proposed are the following:52239 tonnes / year.

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7. PROCUREMENT PHASE

7.1 Introduction

The construction of the network route was required to be conducted under two separate contracts due to a major road improvement scheme in the area.

The section to the North of the route near 100 Temple Street was already under the road improvement scheme and therefore a civils contractor was already appointed and once the scope of the deliverable was agreed we sought a variation on the contract to include the additional heat network route within their site boundary.

The southern section of the route from Redcliffe Mead Lane to our existing energy centre was conducted under a separate procurement exercise

However, there were substantial lessons learnt from both contracts that will be discussed.

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The drawing below, show the boundaries between the two contracts as a dotted red line

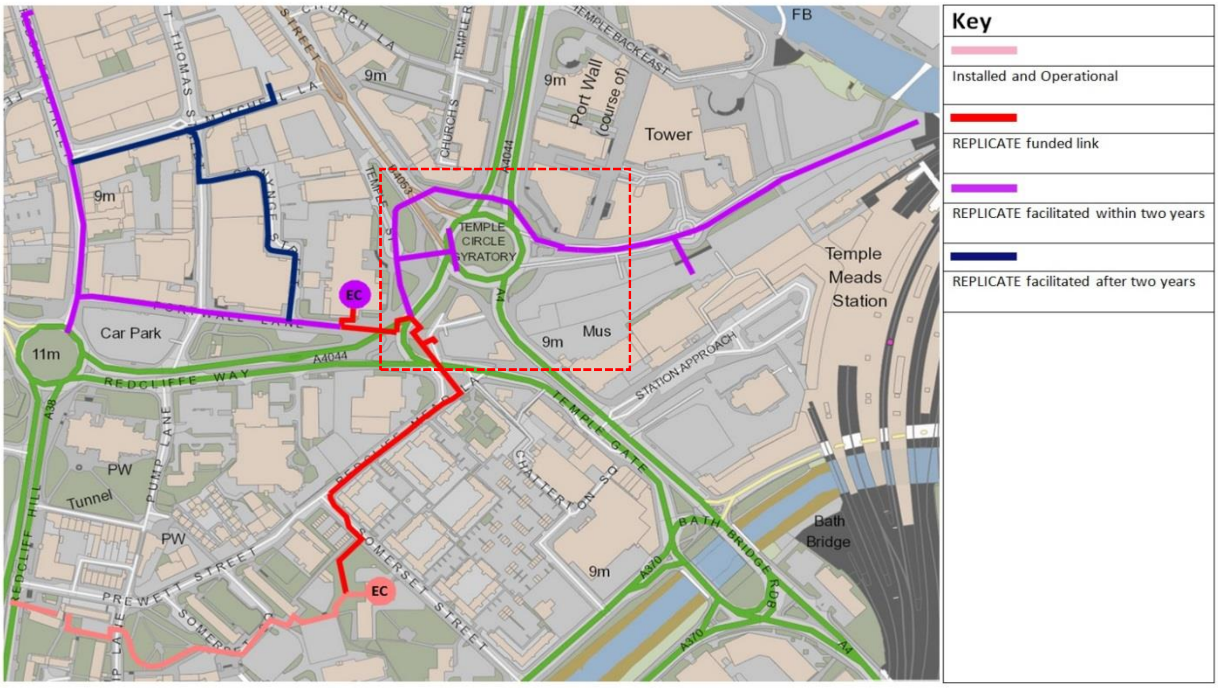

Figure 2: Heat Network Development showing extent of ongoing road works during the project[1]

7.2 Support Services- Design and expert consultant support

The first stage of procurement was to employ technical designer and consultants to support the Bristol team in the main procurement of a suitable contractor. It was decided to complete some of this work while waiting for the final agreement to the Project's scope during the summer of 2018.

We instructed the same designers and consultant practitioners that had been working on an adjacent section of pipework to complete a detailed design of the Network route.

Bristol opted to proceed with a client led design on this project rather than procure under a traditional 'design and build' contract as it was seen that this would have several advantages in terms of timescale and quality control. These are discussed further in the lessons learnt section.

[1] REPLICATE 'facilitated' sections are not funded by REPLICATE funding. These additional connections will be funded separately to REPLICATE in the future as they can only proceed if the proposed REPLICATE connection (red) is installed first (hence the REPLICATE connection facilitating / enabling these future connections).

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The same consultants were employed as Designers, Project Managers, and Supervisors under the contract and also to act as practitioners on the project as client advisors. The consultants employed were 3D Technical design and HN Associates who have worked closely together in the past on projects

The consultants highlighted that an experienced Commercial Practitioner is amongst the most important roles within a construction procurement and delivery process.

The core value of the Experienced Commercial Practitioner is to support risk reduction and facilitate parties being informed and focused on commercial excellence, through consistency and clarity of scope being maintained throughout the process.

Delivering Heat Network infrastructure in the UK brings together complex; technical, commercial, financial, stakeholder management, programming, and construction contract management requirements. The unique blend of closely dependent mechanical and civil processes requires strong governance and quality assurance to ensure delivered outputs are fit for purpose.

BCC chose to encourage a collaborative and open project between designers/consultants, the contractors and the client as it was felt that this would be able to de-risk the project upfront and have a team that would work towards the same aim, which is successful project completion.

This set a tone of working together between parties as all too often in the construction industry in the UK there are issues and misunderstandings left till the end of the project that then need to be resolved. By setting the correct tone and backing this up with regular review meetings issues on the project could be identified early and worked on together to minimise cost to the client while also protecting the contractor against loss.

7.3 Existing works programme (Bristol Temple Circus Improvement works incorporating part of the route).

One of the operational difficulties with this project was that there were major road improvement works in the area meaning that we had to work within the constraints of an existing contract.

Bristol was able to amend the scope of the works to extend the district heat route to include the section required for the REPLICATE project – however, due to the fact that this project was for much wider works that needed to be programmed to suit the road improvement as a priority , the REPLICATE project team was not under full control of the timeline for this part of the works. Due to the historical ground conditions the works had suffered delays in other areas and this presented a risk to the project's completion date. However all parties and teams pulled together in order to get it commissioned in the correct time.

7.4 Main Pipework Contract.

Initially BCC opted to use an existing highways framework. This framework had been designed and set up by BCC highways department to cater for a wide variety of roadworks.

The advantages of this procurement method route were that:

- The framework contractors had already been pre assessed on price and quality.
- The time for the procurement and assessment of tenders would be quicker and involve less internal work
- BCC had already invested in these contractors
- The contractors understood BCC requirements and were either based or working locally

For this tender we followed the Standard Manual for Highways construction in the UK and employed an NEC (NEW Engineering Contract) Option B contract as the framework stipulated. This option of the Engineering and Construction contract asks the contractor to provide a fixed price for the works with a table or rates for each item. This can lead to high additional costs to the Client if there are changes in the works – this is likely when digging up an historic part of a city such as Bristol.

From 5 contractors on the framework we received only 2 bids, one of which we had to discount and the other's price was far in excess of our estimates so for financial reasons we opted to cancel the tender process.

We asked the framework contractors for feedback on how we could encourage more of the market to engage with the project and more detail of this is in the lessons learn section.

At this stage we were instructed to discontinue any work at risk as there had not been final agreement, even though this would set the project back and put at risk our ability to complete the works in the required REPLICATE timescales.

The feedback process led us to re-tender on the open market under a different set of standards and contract more aligned with the utilities industry in the UK.

The specification for the civils element was used the National Roads and Streetworks Act (NRSWA) that controls the way in which services are installed in the highway rather than the more complicated SMHW the highways framework utilised. We also opted for an NEC option C (Target Cost) contract as this form of contract generally works well with projects that have an unknown quantity of changes. As the contractor is paid on actual costs and any deviations from the tender price (target cost) are shared it prevents contractor over inflating prices when changes occur in contract. This also allowed the council to work collaboratively with the contractor as well as the NEC3 Project Manager, as all would benefit from a well-run and open book project.

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7.5 Controls upgrades to Broughton House

As relatively low value this part of the works was let as a 3 quote process meaning that BCC invited 3 specialist companies to tender for the works – the advantage of this is that the whole tender process can be lighter touch and the client can approach contractors that are known to be capable of completing the work.

7.6 Upgrades required to 100 Temple Street.

The project also required upgrades to the internal heating system at 100 Temple Street in order to allow the heating network to deliver heat to the building heating system. However none of this element has been claimed in the REPLCIATE funding claim but is integral to the project's success.

As the timeline for the overall project had slipped as final authorisation to proceed was not given until October 2018 it became feasible to combine the upgrade works with the wider CHP energy Centre project. The energy centre works were split into 2 phases to allow the heat to be delivered ahead of the CHP being fitted as this would be outside the required timescales.

8. TECHNICAL INFORMATION

8.1 Pipework

One of BCC's aims in the development of the network is to raise standards in the industry. This is not only to ensure that BCC receives a well installed, resilient network that is less likely to incur repair costs in the future, but also to encourage the market to provide a higher standard of work across the UK. With a growing industry and new entrants to the market it is seen that this is a good time to ensure the market innovates and employs the correct expertise and methodologies.

This desire is reflected in the technical specification and drawing details shown below and also the innovations and changes that are discussed in the lessons learnt section.

The pipe material is a pre-insulated bonded pipe system for an underground hot-water network. The pipe assembly is steel service pipes, polyurethane thermal insulation and outer casing of high-density polyethylene.

The following norms are met as a minimum by the complete system:

- BS EN 253: Pre-insulated bonded pipe systems for buried heating/cooling networks;
- BS EN 448: Pre-insulated accessories for buried heating/cooling networks;
- BS EN 488: Pre-insulated valves for buried heating/cooling networks;
- BS EN 489: Polythene joints & connections for buried heating/cooling networks;
- BS EN 13941: Design & installation of pre-insulated pipe systems for buried heating/cooling networks.
- BS EN 14419: District Heating Pipe, Pre-insulated bonded pipe;
- ISO 4200: Plain end steel tubes, welded and seamless -- General tables of dimensions' tolerances and masses per unit length

All piping material, valves and other equipment supplied for the distribution system, are designed and approved by the manufacturer for a minimum of 16 bar and 120°C continuous operating conditions. In order to obtain the optimum bond between outer casing and PUR-foam, the inner surface of the outer casing is subjected to a corona treatment during extrusion.

Pipes and fittings are equipped with two copper alarm wires for connection to an electronic moisture surveillance system.

The dimensions of the steel pipes are in accordance with BS EN253 and as a minimum be in accordance with the table below. The strength properties of the steel equal or exceed the minimum requirements in BS EN253.

The insulation material is CFC-free polyurethane and comply with BS EN253. The core density is not less than 60 kg/m3.

The thermal conductivity is not exceed 0.028 W/m,K at 50°C with the required min. core density 80 kg/m3 (before aging).

8.2 Technical detail of the controls required to meet REPLICATE monitoring requirements

The support services associated with this part of the project will comprise of several packages of work that are described below.

The development of an additional I/O controls schedule for all new or modified equipment and sensors (following the design changes outlined in Task 1) for the Trend control system upgrades.

Review of the overall specification of all controls changes needed, including Functional Control Description for the Trend controls upgrade to provide additional capacity to allow Broughton House to be a producer and consumer of heat from the network, as well as facilitating data transfer from the Danfoss outstations (Yeamans, Proctor, Patterson, Spencer etc)

Supply and install of data converters required to link the Broughton Trend BMS and any outstations to common protocol; this will convert data from Trend and Danfoss controllers to open source data that can be transferred to cloud data storage. This will include conversion of Broughton Modbus output to MQTT/API

8.3 Broughton house Energy Centre controls

8.3.1 System overview

A Trend Excite controller is installed in the basement Energy Centre of Broughton House. There are two panels: MCCP1 which is the main panel with main controller and is connected to the gas boilers, biomass boiler, thermal store and main plant room equipment and a separate MCCP2 panel which controls the 12 pumps for the 5 heat network zones.

Connected to four of the heating zones are seven substations that form the interface with the main Broughton House Energy Centre and the building heating and hot water systems.

8.3.2 Substations

The substations comprise five heating zones:

- Broughton House (a zone that supplies a single plant room at ground floor level directly above Broughton House Energy Centre)

- Yeamans House (a zone that supplies a single plant room in the basement of Yeamans House)
- Proctor House and Patterson House (a zone that supplies two buildings via plant rooms in the basements of the two housing blocks)
- Canynge and Spencer (a zone that supplies two substations, one in Spencer House basement plant room and the other which supplies Canynge Energy Centre)
- Waring House (a zone supplied from Canynge Energy Centre that supplies a single plant room in the basement of Waring House)

A network zone which is set up but yet to be connected to the wider heat network

8.3.3 Control Equipment

The existing Trend Exite Controller must be fitted with the hardware required to connect to the additional equipment, meters and functionality and therefore the project was required to supply and install the additional hardware, software and cabling:

A summary of the Mbus and Modbus cable requirements is given in the Control Communication Schematic shown below

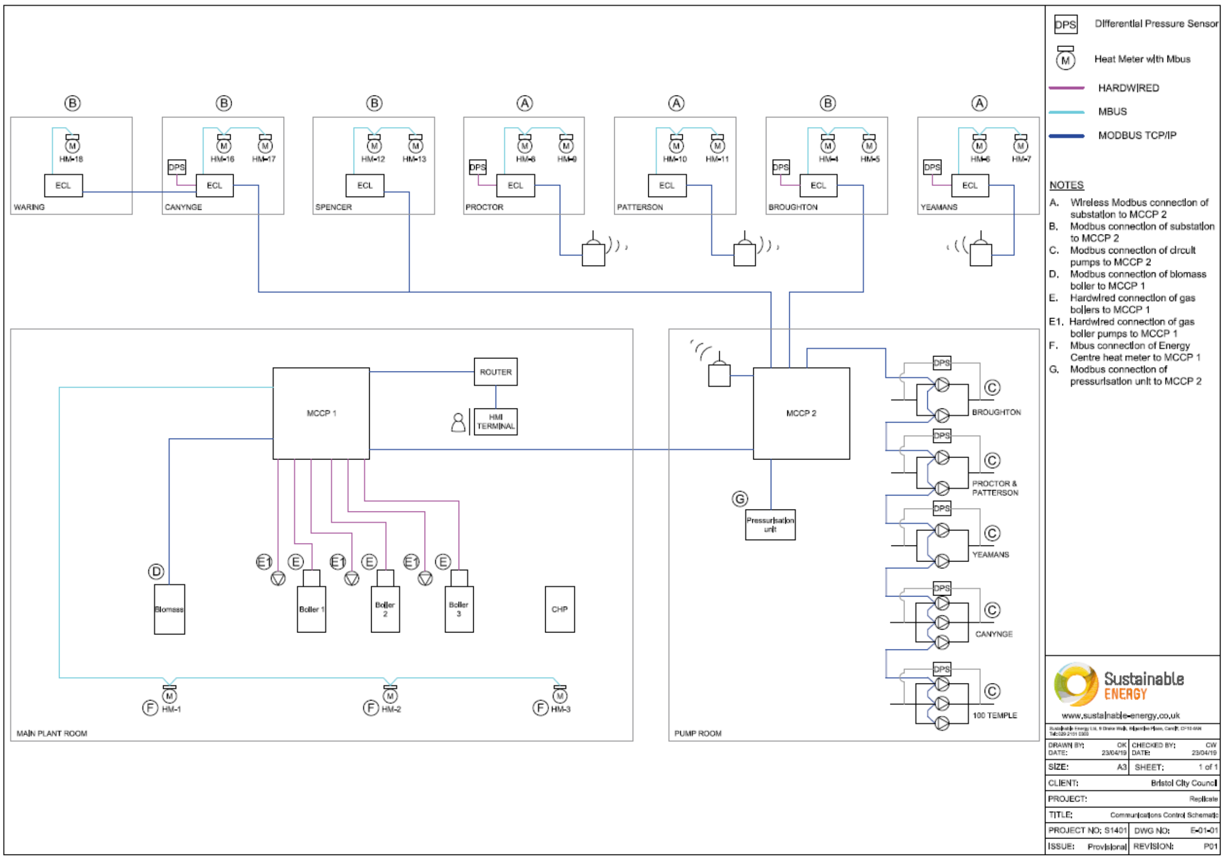

Figure 3: Schematic for control equipment

8.4 Future Provision for Heat Import

When the new Energy centre at 100 Temple Street is commissioned it will be necessary for the existing network via the Broughton house energy centre to import heat to the Redcliffe network. This is so that in the early years of the wider network operation, where there are few commercial connections we can make most use of the more efficiently produced heat form the CHP unit. The site is planning to install additional equipment (under separate contract) such as control valves, sensors and heat meter to allow the import of heat to Broughton House Energy Centre from a wider heat network.

Part of the resilience and future-proofing strategy is to ensure all hardware and software installed as part of this contract is fully functional and ready to accommodate the further mechanical and electrical works.

The contractor is to allow additional Trend system I/O to provide control of additional Control valves, sensors and metring in order to future proof the system.

8.5 Functional Control Upgrades

Two areas of control program improvements are required:

Set up of pump speed control for all 5 pumps sets with two set point differential pressures (one for local differential pressure sensor and other for remote sensor) within BMS to allow proportional control such that set point reduces with pump speed

Set up of modulating control for gas burners (this is already written into main system code but not functional). Optimise temperature control (PI optimisation) from gas boilers

8.6 Primary Pump Operation

There are five network distribution zones comprising three zones with duty and standby and two zones with duty, assist and standby pumps installed (12 pumps overall).

The pumps are currently operating with speed control provided by the individual pump controllers.

The pumps should be connected via Modbus and the speed control should be provided by the BMS.

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For the zones with three pumps, one pump is lead (actual pump in operation depends on rotation status); one pump is in assist status, and the remaining pump is in standby status. Therefore, there will never be more than two pumps in operation at any time.

Additional assist pump will be activated by the control loop based on maintaining a desired differential pressure at the sensors installed within the network

Speed control output changes are to be on the 'little and often' principle in order to facilitate gradual incremental system value changes specifically to avoid hydraulic spikes/shocks.

Activation of additional assist pump requires that activated pumps return to minimum speed before activation of additional pump; the activated pumps will then increase speed together. Once activated, assist pump will remain in operation for at least 300 seconds (Engineer adjustable).

There are two modes of operation – local or remote differential pressure control.

Each mode is to be selectable via the Engineer's page with a software switch. Whichever mode is active will be displayed on the main page.

In 'remote' mode, the pump speed is modulation controlled to maintain a proportional differential pressure at the substation installed on the zone (this data is provided by Modbus TCP/IP). Remote DP sensors will be connected to Danfoss ECL controllers and provide signal via Modbus

In 'local' mode, the pump is to be speed controlled to ensure the differential pressure across the main system flow and return lines in the Energy Centre are always maintained at set point

The desired differential pressure setting for the Energy Centre sensors is adjustable at Engineer level.

In remote mode, the pumps are to be speed controlled to ensure that a set point differential pressure is maintained across each of the 5 circuits.

If during operation in remote mode the differential pressure measurement at the selected branch is lost for a period of 5 minutes (to be adjustable at Engineer level) then the control of the pumps is to revert back to local mode with the differential pressure sensors across the main system flow and return lines in the Energy Centre.

The remote differential pressure sensors are system critical; if one fails then the flow control will revert to the Energy Centre differential pressure sensor default.

8.7 Gas Boiler Control

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The existing gas boiler control operates the 3 gas boilers to achieve the set point flow temperature.

The burners are modulating burners and the control blocks have been set up to vary capacity of the boilers, however, the function is not correctly operating and the burners just fire at 100% once PI control level exceeds 50%. This control arrangement requires remediating to modulate burners from 30% to 100%.

The individual boiler pumps are enabled with each boiler.

A revision of the control is required to set speed control from 30% to 100% (Engineer adjustable) to correspond to boiler capacity control.

8.8 Substations

There are several buildings (substations) which are supplied with heat from the Broughton Energy Centre and connected by an underground heat network.

Seven of these buildings are required to be connected to the Trend BMS to monitor the local substation controllers in each building. The substation controllers are Danfoss ECL 310 controllers

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9. CONSTRUCTION PHASE

The works sought to embrace CDM, commercial and technical best practice to address several prominent UK buried heat network construction challenges;

- Often an inadequate volume of Pre-Construction Information is developed and used to de-risk/inform construction.
- Adversarial contracting and pricing practices leading to un-collaborative, and often adversarial working practices
- Focus on cost and time, leading to poor quality and project outcomes

As a progressive "Client" BCC set out as an organisation to facilitate a more informed and collaborative relationship between; Employer, Contractor, Project Manager and Supervisor (a strong element of successfully operating the chosen NEC model form contract).

The level of investment placed on pre-construction information and coordination facilitates a prompt mobilisation period, and the works on the Redcliffe Mead Lane Link to Broughton House began in March 2019. For this section of the build the key project team consisted of the Client (BCC), the NEC3 Project Manager (HNA) and the Contractor (CSW Process). Alongside this was the Principal Designer (3DTD), Cost Consultant (Currie Brown) as well as a full time NEC3 Supervisor (HNA) on site.

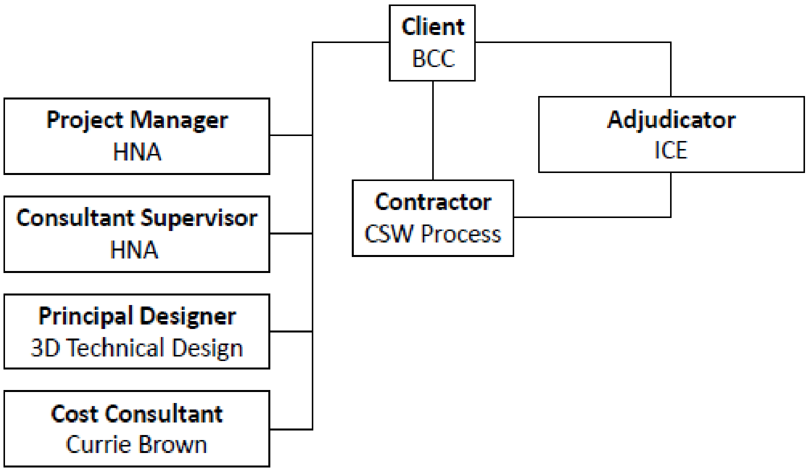

Figure 4: Contract/management structure of this section of the project

With the engagement of an impartial NEC3 Project Manager effectively sitting between the Client and the Contractor it allowed for any issues/compensation events to be dealt with quickly and effectively. To complement this, the client engaged a specialist design consultancy to undertake in-construction design changes promptly.

BIM 360 was used to house a 3D design model and common data environment, and contract administration and project management structures were also set up and trained to all users from the beginning, through the use of construction contract management software (CEMAR). The software handled all contract communications that help to manage the project including the programme, early warning notices, defects, payment certificates and variations and/or instructions (Compensation Events) to the contractor.

Learning from local projects allowed BCC to recognise the benefits in early investment in both the pre-construction information and the need for well-resourced risk management practices to identify, avoid and minimise the challenges commonly associated with urban buried environments.

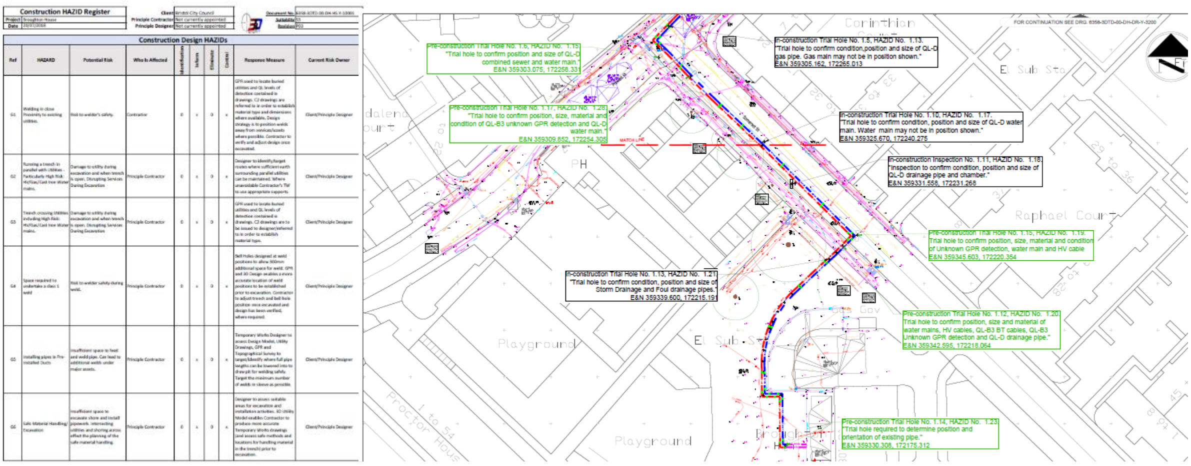

Figure 5: Extracts from the designer's risk assessments and annotated/prioritised verification strategy.

D5.2 Connection of a 13 block (700 flats) district heating network to a gas CHP energy centre

At the start of the project a number of key trail holes were dug to verify the positon of key existing assets within the highway (such as telecoms & water mains). This allowed the Principal Designer to verify & amend his design in preparation for the remainder of the construction process.

As the client elected to operate a client-led design strategy rapid changes to the trench depths and pipe installation detail could be made both quickly and with a focus on long-term quality of the network. This strategy allowed sufficient specialist resources would be available to ensuring that the contractor could re-commence excavation promptly leading to a minimised impact to the contract programme.

The success of this structure in relation to design change control and efficiency, meant that a contractor request to amend the programme to excavate the final two phases consecutively could be actioned and controlled. With two phases open costs associated change were minimised as excavation gangs could be re-deployed during welding and re-design processes.

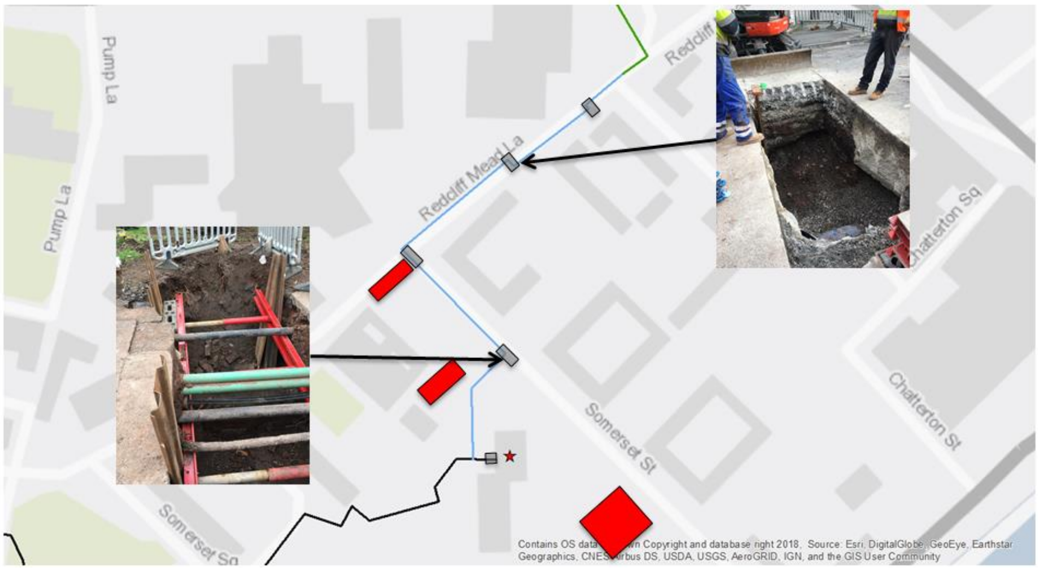

Figure 6 – shows the trial holes across this section of pipe

By having these controls and constant verification in place in allowed for a relatively smooth build process, and collaborative working was encouraged by BCC from the kick off meeting, where parties established that between the client, contractor, PM, supervisors and designers there were unique skills and experiences which could support the emergence of the industry and enhance the competence and quality systems of all organisations.

An example of the close cooperation between the various parties is in how the programme was developed from tender stage to NEC compliance, and updated. The programme update process occurs every two weeks under the NEC where the contractor submits actuals to the NEC Project Manager for acceptance. Parties undertook the updating jointly leading to constant accepted/updated programme being in place throughout.

The figure below shows how the, pre-construction document submissions, trail hole, and construction phases were initially planned in the contract programme

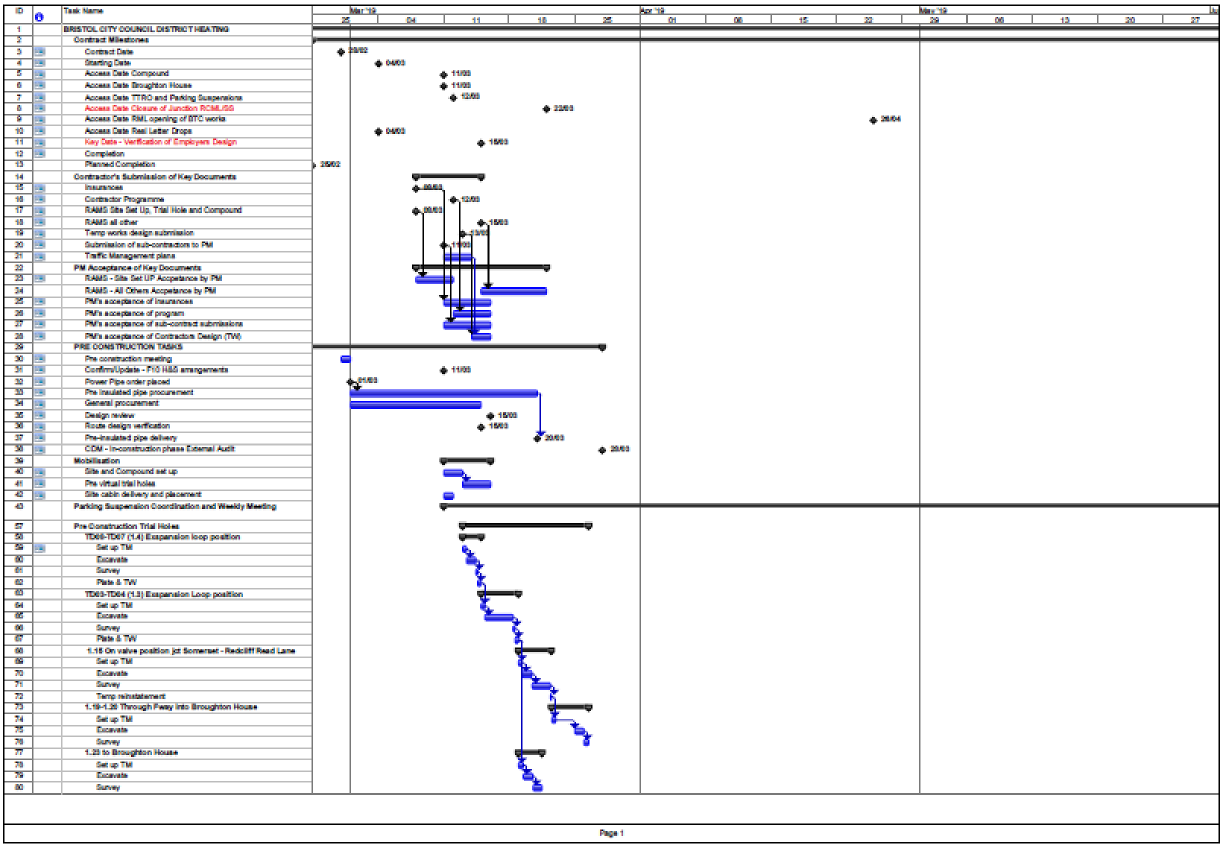

Figure 7 – Snapshot of Pre Construction works programme

Additionally, BCC's team utilised their experience to ensure adequate forward planning by attending all project meetings and their prompt reference to the minutes and updated contract phasing/programme phasing ensured coordination of all necessary parking suspensions.

HEAT NETWORK ASSOCIATES

HNA Meeting Minutes and Notes 2019

Appendix 2 – Requested Parking Suspensions

TM	Road	Bays	Reference Point	From	To	Suspension Number	Bay Days	Notes
Suspension	Prewett Street	2	Outside the Kiln	11/03/2019	30/06/2019	4984458683111150000	222	Applied
Suspension	Redcliff Mead Lane	6	Bays opposite the two entrances to Tiffany Court	13/03/2019	17/03/2019	7246912024008420000	24	Applied
Streetworks Notice	Redcliff Mead Lane	N/a	From Junction with Temple Way and Somerset Street	11/03/2019	28/06/2019	QF018 3600001	N/a	Actual Start
Suspension	Redcliff Mead Lane	6	Bays opposite the two entrances to Tiffany Court	18/03/2019	02/04/2019	8023331625308330873	90	Applied
Suspension	Redcliff Mead Lane	5	Next to the NR Carpark	18/03/2019	02/04/2019	3132616536270733813	75	Applied
Suspension	Summerset Junction with RML	3	First three Bays opposite garages	21/03/2019	27/03/2019	3053952165405330469	18	RL to suspend
Suspension	Summerset Junction with RML	2	Two bays where route turns into grassed area (wall to be taken down) footpath towards BH.	21/03/2019	27/03/2019	4095259290521559255	12	RL to suspend

Figure 8: Management of Parking Suspensions

The open and honest approach by all parties led to a culture of transparent in quality management, and the Contractor openly shared the defects which it was identifying and correcting in the works. This level of collaboration aligns with best practice project and quality management recommended by NEC.

It is to the credit of the contractor, the onsite project management team and the way that the designers worked together that led to a very smooth construction phase for the main pipe installation.

Health and Safety

CDM best practice transferred well from the pre-construction to construction phases, with the Principle Designer reviewing the contractor's RAMS and specialist mechanical practitioners also available to comment and enhance the method and controls associated with the tests on completion.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The project has maintained a Construction Phase Plan which has been updated during the works to reflect issues with tree protection compliance and end of week checks.

The project had zero near misses and reported accidents during construction.

Traffic Management

The Works were undertaken in an area which was significantly affected by local highways re-configuration of the Temple Circus Gyratory system at the base of Redcliffe Mead Lane.

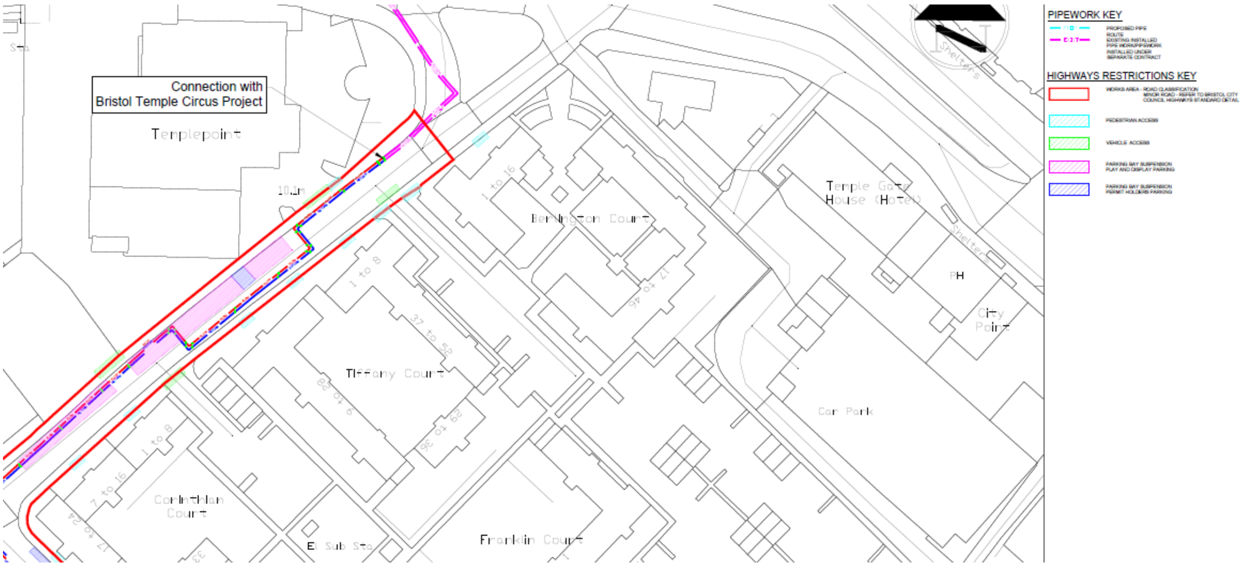

Figure 9: Traffic Management Drawing

This meant that additional TM coordination between projects was necessary in order to plan material deliveries through potential restricted routes, diversion routes from BTC as well as maintaining vehicle and pedestrian access to residents and key stakeholders including Network Rail.

A TTRO was implemented which could have facilitated a full junction closure at Somerset Street/Redcliffe Mead Lane junction. However, detailed coordination between all parties enabled a plating strategy to be implemented to re-open the junction promptly.

Road plating strategies were also implemented to maintain vehicular access to buildings and residents when the DHN trench crossed their access routes. Overall, coordination and effective construction techniques led to minimal stakeholder impacts.

Phasing

The works construction was split into 5 phases, to enable the route to cross the carriageway and key junction at Summerset Street, and also to identify a low impact phase (5 – Broughton House Land) which was off highways. Phase 5 was programmed off the critical path, to allow float in the remaining 4 phases.

Figure 10 – Snapshot or Construction works programme across 5 Phases

The phasing strategy enabled teams to promptly relocate and undertake works in this phase during any periods of surveying and re-design, and also when welding activities were being undertaken in the early phases.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

During the works, there were a total of 12 days Extension of Time events awarded by the Project Manager for factors including; breaking out additional concrete, re-design moving the route into kerbs and requiring additional re-instatement, 14 additional welds and safely implementing a temporary works strategy to protect a high risk buried water main which ran adjacent to the trench.

Despite these issues (common examples of the risks associated with a predominantly under-mapped buried environment in UK), the phasing and programme management techniques deployed enabled the works to be completed ahead of contract completion date. This outcome is closely attributed to the collaborative delivery model, detailed pre-construction risk management, practitioner level support, and continued focus on the project's quality plan/systems.

Stakeholder Engagement

BCC took a leading role in ensure regular liaison was undertaken with the local residents affected by the works. A key positive in the process was understanding how stakeholders were affected by the works and implementing reasonable measures to demonstrate the project would benefit the wider community.

Following a series of resident meetings, where BCC's project manager delivered progress updates to residents, local enhancement measures were instructed/offered by the contractor and included; installed security posts to prevent unauthorised use of garage parking and fully reinstating aged footpaths affected by the works.

Figure 11: Image showing improvements to security for residents

During weekly Project Coordination Meetings, stakeholder initiatives were discussed/planned and project data required to inform local communication strategies/marketing was exchanged.

Challenges

As is commonly the case in UK urban deep excavations, there were some difficulties during the project, primarily due to a large water main that had been repaired in recent years and created unstable ground conditions along the trench route.

The photos below show some of the trench and temporary works to illustrate this.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Figure 12: Trench showing existing water main

A further challenge came from local available compound space for the works (owing to a combination of adjacent construction works and availability of suitable storage space for 12m rigid pipe, curves and large volumes of reinstatement material and muckaway. The challenge was overcome through splitting project offices from storage, hosting key meetings at BCC and using foam concrete which is delivered direct to trench as opposed to maintaining a stock of MOT Type 1 compaction material.

Figure 13: Trench showing pipe installation

Additionally, the route options in phase 5 (Broughton House Land) were constrained by future development works planned. Therefore, curved pipes were used to minimise the route extending into planned development zones.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Highways Improvements

Due to the unstable ground conditions the strategy for back fill was changed from a standard granular fill to the use of foam concrete. While this added cost to the project it made the road structure much safer and less liable to sinking in the future due to the foam's expansion filling voids and soft areas in the sub-base.

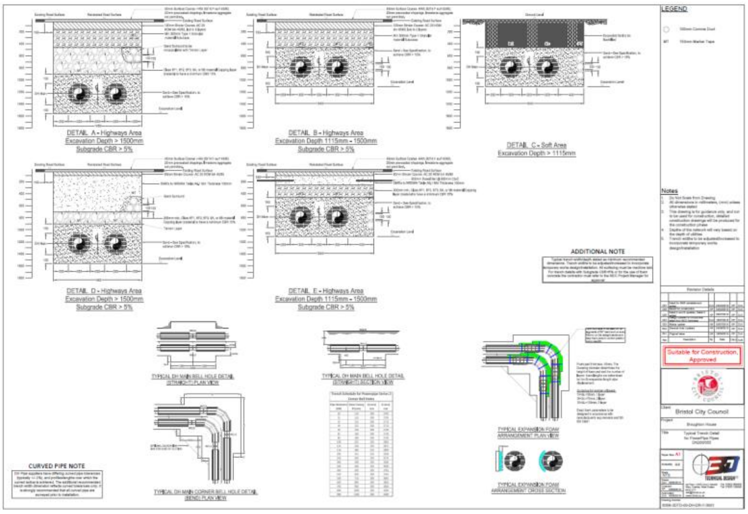

Figure 14: Trench detail drawing

The photo below shows how the foam concrete needed to be brought up in levels due to the slope of the road.

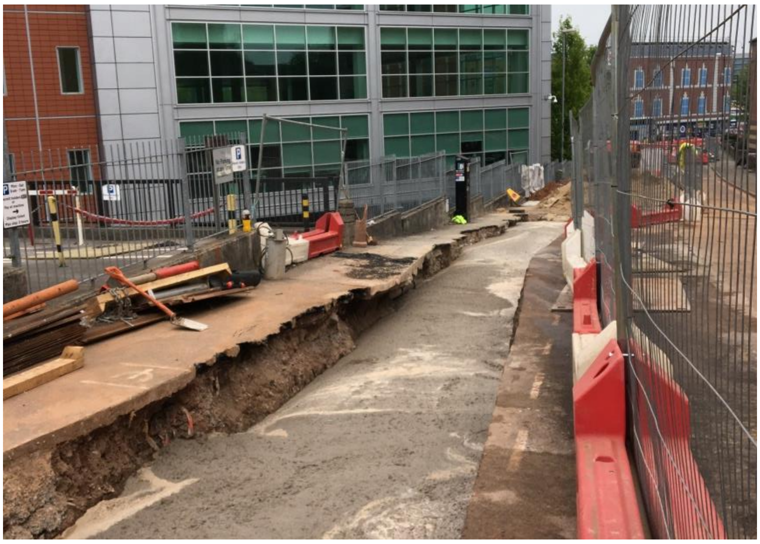

Figure 15: Trench with foam concrete backfill

Quality of work, testing and records.

A key outcome of the project was the documented quality of the works. The Contractor, PM and Supervisors agreed a series of witnessed tests throughout the delivery of the works which ensured key quality criteria were met, which would extend the life of the buried network in operation, these measures included;

- The project was the first buried networks to phased array test all welds to Class 1.
- CBR tests were recorded of all backfill material and sand surrounding the pipe.
- Alarm wires were tested for continuity and insulation resistance throughout the project and analysed at completion to demonstrate functionality.
- Pipework was pigged and hydraulically tested to achieve 16 bar (strength test).

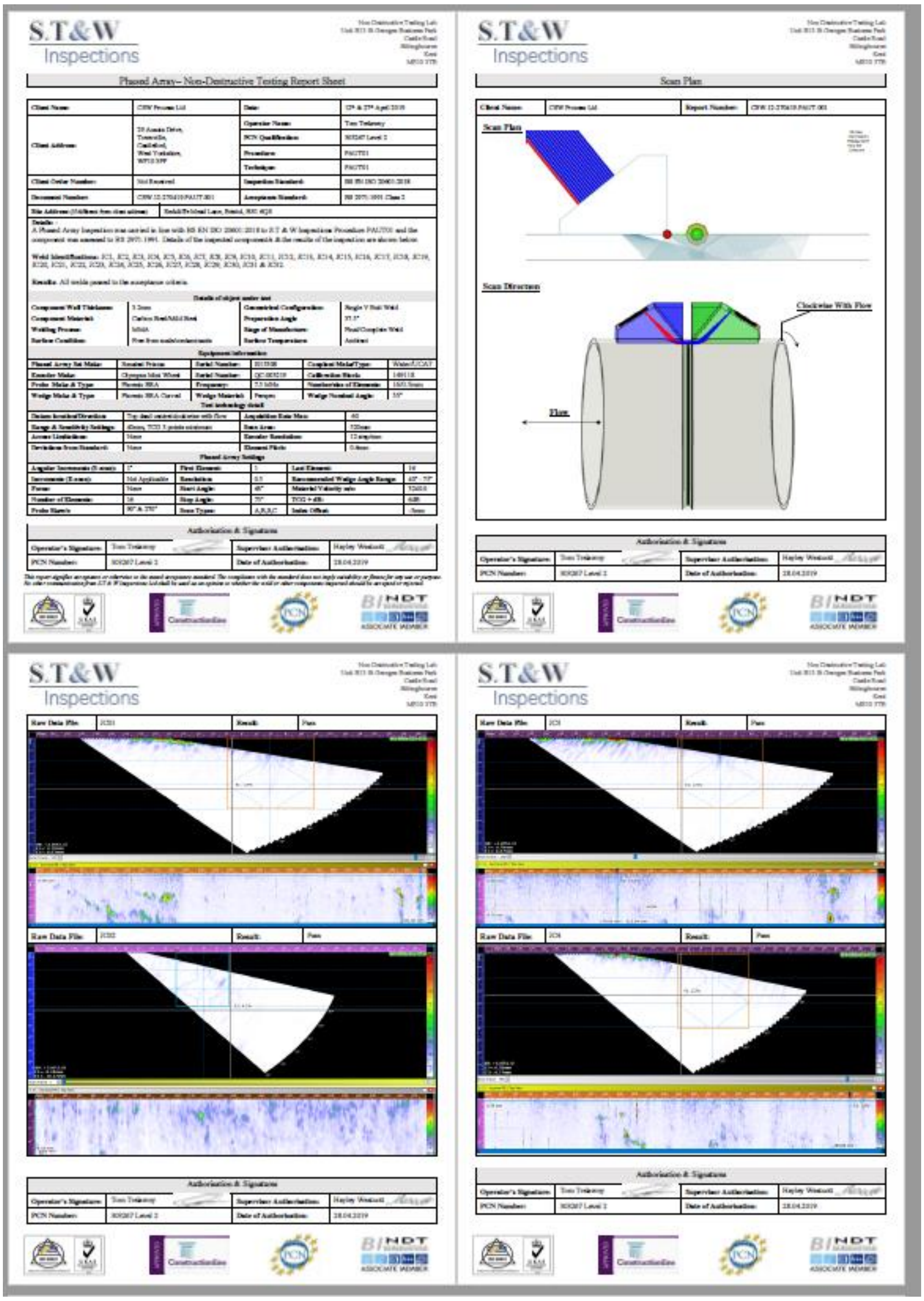

Figure 16: Phased Array Test Results

Non-conformances were professionally raised, reviewed and closed throughout the works, as well as a detailed defect correction/acceptance process.

HEAT NETWORK ASSOCIATES 2019

Notice of Non- Conformance Form

Project Name	Project Number	Non-Conformance Number
Bristol Broughton House	6358	NC1

Details of Non-Conformance Covered Within This Notice

Implementation of construction free zones and Tree Protection Plan, particularly as contained within Appendix 2 of AIA TPP - Broughton House - 12.10.18

Below – pictures of existing set up and TPP contained within Site Information

Identified by:	Date Identified:	Contractor:
BCC – Representatives	12/04/19	CSW

Issuing Person:	Reported to:	Date Issued:
Craig Grobety	Jamie Cartwright	12/14/19

Investigation

CSW to conduct a detailed review of all site information documentation.
Meeting with BCC representatives on site Monday 15/04/19 to review measures implemented.
Meeting with NEC PM to discuss non-conformance and lessons learned.

Investigated by:	Investigation Date:	Results Reported To:

Rectification Required:

Immediate action instructed to clear spoil from construction free zone and implement fencing as per Tree Protection Plan 12/04/19 and actions agreed during site meeting 12/04/19 with Employer and BCC representative.

Review of TPP in Site Information and updating of RAMS for works where required

Issued To:	Contractor:	Date Issued:
Jamie Cartwright	**CSW**	**12/04/19**
Inspection By:	**Date for Completion:**	**Status – Complete or Rejected:**

Complete this section to record corrections

Project Name	Project Number	Defect Number

Position:	Print Name:	Signature:	Date:
Supervisor/Representative Position:	**Print Name:**	**Signature:**	**Date:**

Library File Number – 6358_Notice of Non-Conformance Form

Detail	Rev	Author	Date Reviewed	Reviewed By	Next Review
Original Draft	1	C Grobety	08/03/19	DJU	March 2020

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Figure 17: Non-conformance paperwork used in the contract

10. CONTROLS STRATEGY

This section of the project aims to improve monitoring, remote access and some control improvements. The data collected will be used by a cloud based prediction and optimisation system to advice on optimum use of technologies and network conditions.

Initially the data will be collected to enable the Required REPLICATE monitoring but the changes designed and planned to allow remote system tuning and smart optimisation of the network in the future. Bristol has opted for a step by step integration of control systems rather than try to enable a smart network from the beginning. This strategy prevents early decisions being made that may negate future improvements here we are ensuring we can 'walk before we run'.

The control changes to be undertaken as part of these works will not affect the overall running of the boilers and pumps, however, slight changes to how the boilers, CHP and pumps are to be operated will require works that will need to be carefully planned and co-ordinated to ensure there is no interruption (or only short term agreed planned outages) of heat to the connected buildings.

The image below shows the basic topography for our ongoing data collection and management

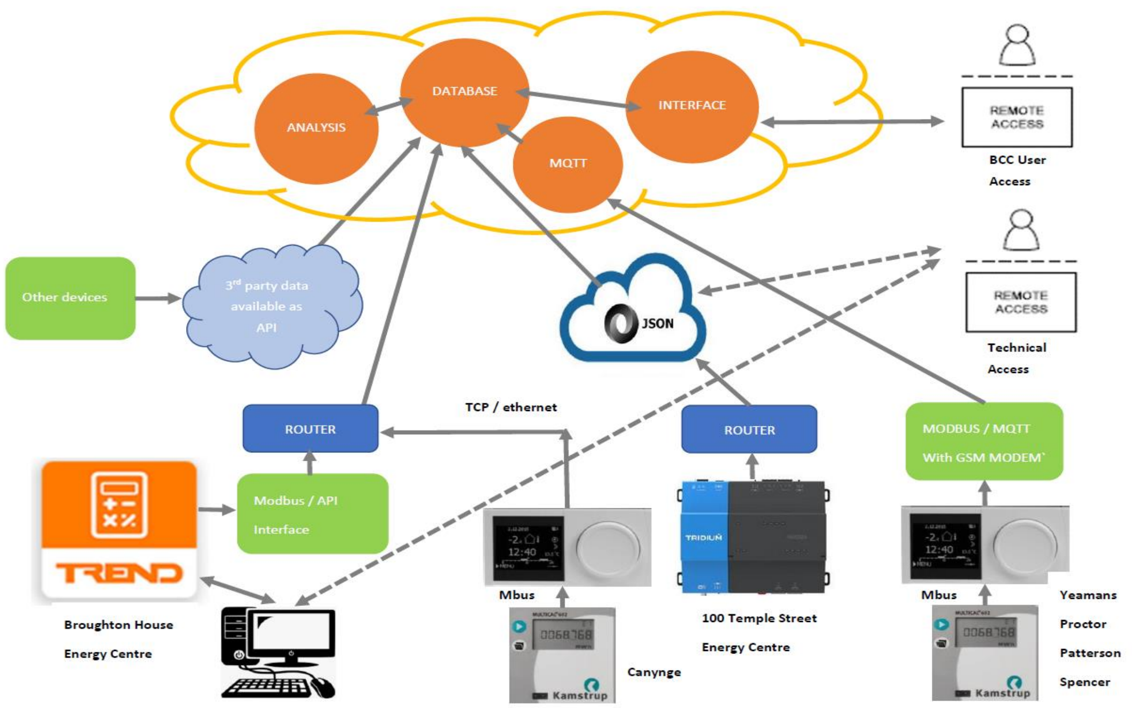

Figure 18: network topography diagram

11. MONITORING STRATEGY

The monitoring strategy will be to provide a cloud data host space with sufficient capacity to store a minimum of 2 years half hourly data for all buildings (including data from 100 Temple Street)

This will include the development of data structure and management system to meet the data submission requirements of Replicate. Analysis of data into format required for Replicate data reporting including monthly CSV files. Final data summary for Replicate reporting (data provision only, no written reporting included)

Additionally there will be provision of multiple users' access to dashboard for data access for full monitoring access from a web browser. This will include overview web pages of network equipment operation, meters, summary cumulative statistics, daily statistics, monthly statistics and annual energy data.

12. LESSONS LEARNT

12.1 Design

12.1.1 Efficiencies in the design process

Previously Bristol has worked with a designer opting for a full 3D design to present to the contractor. An example of this is shown below. With a full 3D design the time consuming and therefore costly element of the designers work is putting together the construction plan and longitudinal sections as shown.

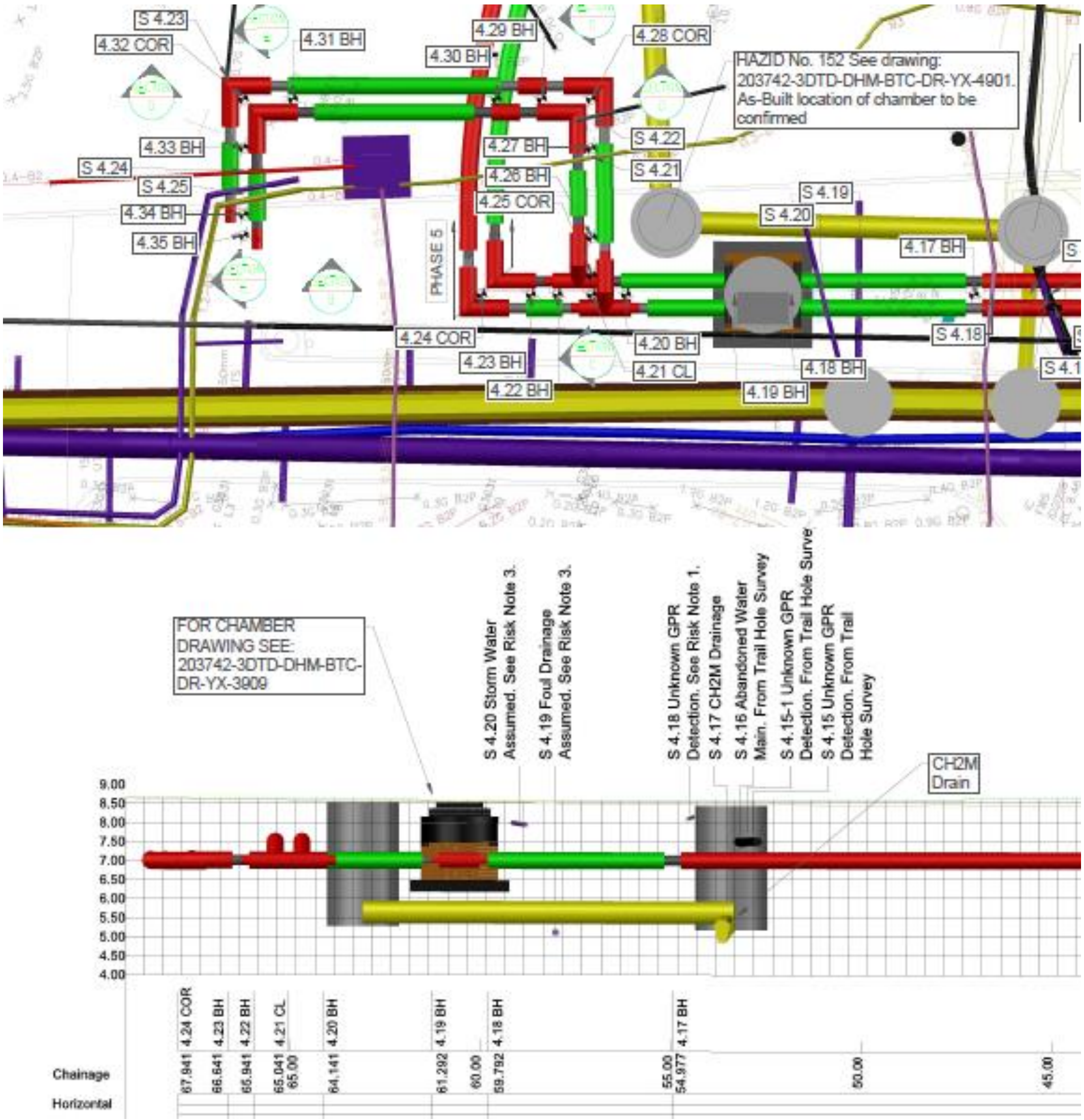

Figure 19: Construction drawing example (part)

For the REPLCIATE project the methodology was changed in order to save time and costs in the design stage.

The designers created a target depth drawing as shown below. This gives the contractor enough detail for most situations to dig the trench to a certain line and depth. Where there are situation that have a high density of existing services the 3D full construction drawings can aid the contractor route the pipe through the higher risk area.

As well as saving time in the initial design phase this method also saves time and cost if there are changes due to clashes with existing services in the construction phase.

Target Depth analysis for trench excavation worked well in terms of a cost effective method of establishing complex areas, HAZIDS and general depths. The process allows for cost effective depth analysis in detailed design and has been adopted by other consultants in the industry following the success of Broughton House.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Target Depth Coordinates			
ID	Easting	Northing	Target Tench IL Depth (m)
TD01	359396.530	172342.620	1.70
TD02	359384.374	172333.455	1.70
TD03	359373.478	172324.642	1.70
TD04	359377.036	172320.244	2.00
TD05	359373.074	172316.943	2.00
TD06	359364.098	172309.942	2.00
TD07	359350.371	172298.658	2.00
TD08	359346.765	172303.027	1.70
TD09	359344.237	172300.937	1.70
TD10	359342.498	172299.463	1.70
TD11	359340.781	172297.963	1.70
TD12	359339.086	172296.437	1.70
TD13	359337.406	172294.896	1.70
TD14	359321.894	172280.684	1.70
TD15	359313.723	172273.317	1.70
TD16	359316.203	172248.082	1.70
TD17	359325.263	172239.511	1.70
TD18	359344.693	172220.187	1.70
TD19	359341.090	172216.563	1.40
TD20	359333.353	172209.375	1.40
TD21	359331.615	172207.720	1.40
TD22	359330.014	172205.934	1.40
TD23	359328.639	172203.969	1.40
TD24	359327.509	172201.852	1.40
TD25	359327.024	172200.746	1.40
TD26	359326.869	172200.377	1.40
TD27	359326.100	172198.105	1.40
TD28	359325.623	172195.754	1.40
TD29	359325.443	172193.362	1.40
TD30	359325.460	172191.027	1.40
TD31	359325.505	172186.098	1.40
TD32	359329.286	172186.132	1.40

Target depth coordinates are intended to provide estimated trench invert level depths and may require adjustments after trial hole surveys and during construction. This table is to be read in conjunction with 6358-3DTD-00-DH-DR-Y-3100 and 6358-3DTD-00-DH-DR-Y-3101 GA drawings

Figure 20: Target depth Table (from drawing)

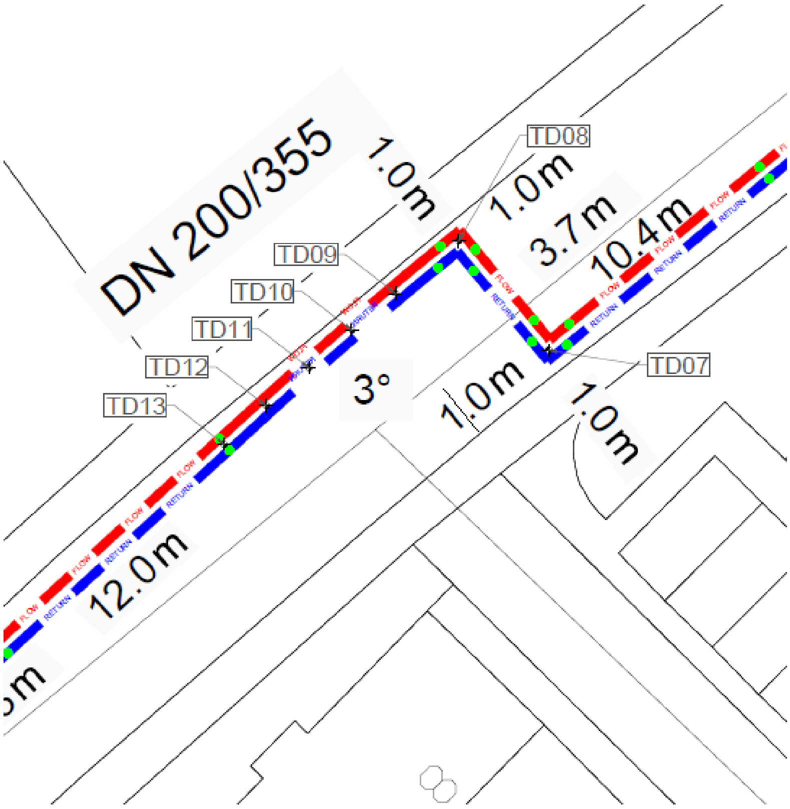

Figure 21: Section of Target depth drawing

12.1.2 Client vs Contractor design

In the UK civils and district heating industry the contractors in the market generally would prefer to control the full design and installation process. The rationale for this is that the contractor can save costs and time by being in control of the whole process. This method of working can work well with the correct contractor but does present risks in terms of quality. Where a contractor faces complications during a project that can add costs and time that is at their risk the tendency will be to cut corners in terms of the quality of the installation.. This can lead to a poor installation, higher costs in the long run for the owner and an inefficient network. .

There are two ways to mitigate this risk. The first within the design and build contracting model is to have very strong supervision and contract management of the project however the strength of response is limited as the contractor has been trusted with the design part of the project.

Another strategy to enable better control of quality of the project is to retain the design element of the project within the client's control. While strong supervision and control management is still required, this design methodology allows greater sight of the works and a closer collaboration between the client and contractor project teams.

The contractor would argue that this presents a greater risk to delay as they are reliant on an external response to react to changes due to unknown hazards and blockages in the underground environment. In reality this can be a risk in either design method and depends on how the change control process is set up and the speed of response of the designer's irrespective of who they are employed by.

Bristol mitigated this risk by working closely with the designers at an early stage to set up a change control process whereby a fast response to any issue could be addressed, advising the team digging in the road to minimise delay and prevent undue cost.

The flowchart that was drawn up for the contractor to understand the process at tender stage is shown below.

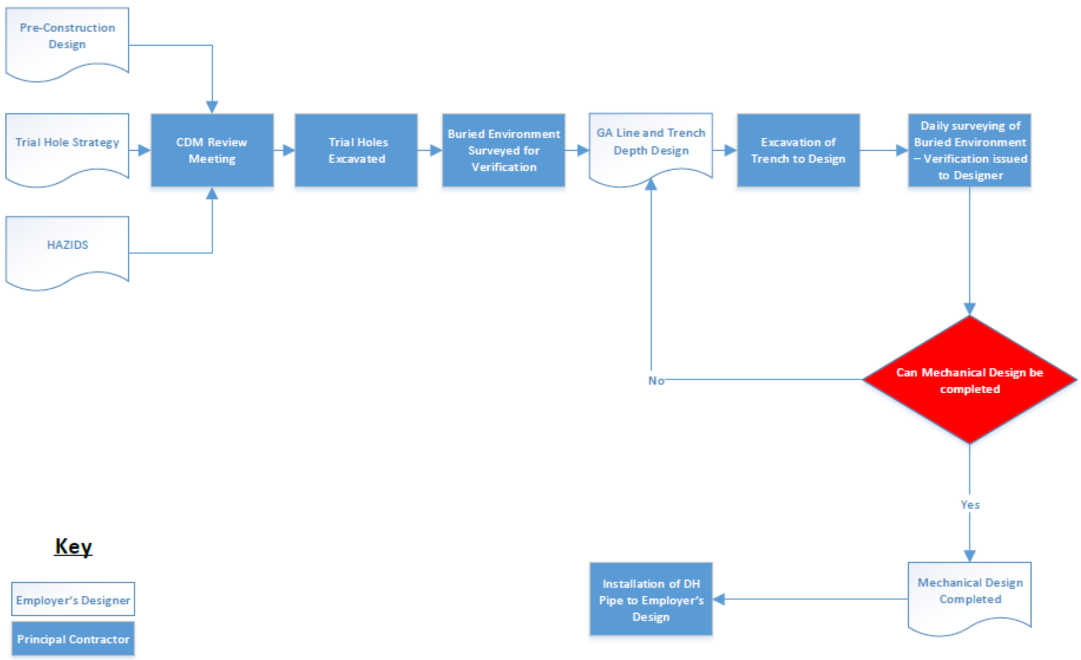

Figure 22: Verification flowchart

Bristol saw the benefits of this process by having zero downtime for the contractor during the project even when design changes were required due to existing services being on the preconstruction design route.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Employer-led design has allowed for responsive and visible changes made in construction to be fed through to the pipe manufacturer to ensure warranty is maintained and programme milestones achieved.

Feedback from Broughton House is to maintain the level of detail on future employer-led designs but to undertake a 3D centreline design to further refine depth positions.

12.2 Contracting Methods

NEC Option C was delivered in genuine partnership between Contractor, Employer, PM and Supervisor. Owing to the collaborative nature of the structure programme was maintained and quality has set a new benchmark.

Use of a smaller Contractor meant that accountable decision makers on site maintained standards and responsiveness. Collaboration with Practitioner PM/Supervisor was improved under this model.

Engagement of a specialist DHN PM and Supervision practitioner team has supported the employer in focusing on strategic objectives and stakeholder communications whilst maintaining faith in the overall delivery/quality of the works.

Commercially, parties have shown a deep understanding of the provisions required for common and planned compensation events which occur in deep civil/mechanical DHN works. This has meant that compensation event assessments have been concluded without protracted differences/disputes.

Stakeholders

Early engagement with Highways and Residents meant that strategic opportunities to consider wider stakeholder needs (parking, traffic management, reinstatement) were captured and delays minimised.

13. INNOVATIONS, IMPACTS AND SCALABILITY

13.1 Innovation solution

Phased Array Ultrasonic Testing (PAUT) implemented

While used in other industries the use of Phased array Non-Destructive Testing is an innovation in the UK Heat Network sector.

The more common method within the industry is manual Ultrasonic testing and there can be issues with picking up welding defects especially in thin wall welds. The ultrasonic detector relies on sound waves that produce an image on a screen (much like an ultra sound in medicine) but the machine does not record any images and therefore any defects and the classification (quality) of the weld is open to interpretation. This means the welders have an opportunity to argue any failures where Manual UT has been used particularly in situations where the NDT engineer doesn't necessarily have the confidence in the test to argue. With the PAUT you have an image (see examples below), this means the tester can show the welders/pipe installers/end client any defects clearly and records can be kept of the inspection. This not only removes a large element of human error and interpretation, but a conscientious welder can be shown the defect, where it is the weld in order to repair it effectively and efficiently but it can also be used as a training and improvement aid. It is similar to X-Ray in this respect as graphs are available to view, but PAUT can offer better images without the risks associated.

Bristol experienced a situation on the adjacent project, where there was lack of confidence that welds were being completed to the correct standard as it was noted that too many were being completed in a day. Through a process of lab testing and collaboration with an independent tester Phased array was discussed, demonstrated and immediately implemented. This methodology was also immediately added to the specification for the REPLICATE funded project.

13.2 Social impacts

It is too close to the project's completion to assess the advantages citizens in the area now have compared to before however the project will provide greater resilience on network for social housing tenants in term of provision of heat and also help to protect them against wholesale gas prices. In the last year the Heat Network has protected the social housing tenants against a 25% increase in UK gas prices.

13.3 Environmental impacts

Although not fully realised yet we expect that the combination of the increased utilisation of the biomass boiler with the greater efficiency of the Gas CHP will lower the overall Carbon factor of the network in the next few years by displacing the gas boilers on the current network and within 100 Temple Street.

13.4 Replication and scalability potential

Template documents and drawings

BCC now has a suite of specifications and template drawings that can be adapted and used for future work. These will not only save time in future procurement exercises but also ensure that the same standards are replicated as the Bristol Heat network is built out.
The example of this below shows the trench detail that was developed in conjunction with BCC highways department to ensure compliance with local requirements.

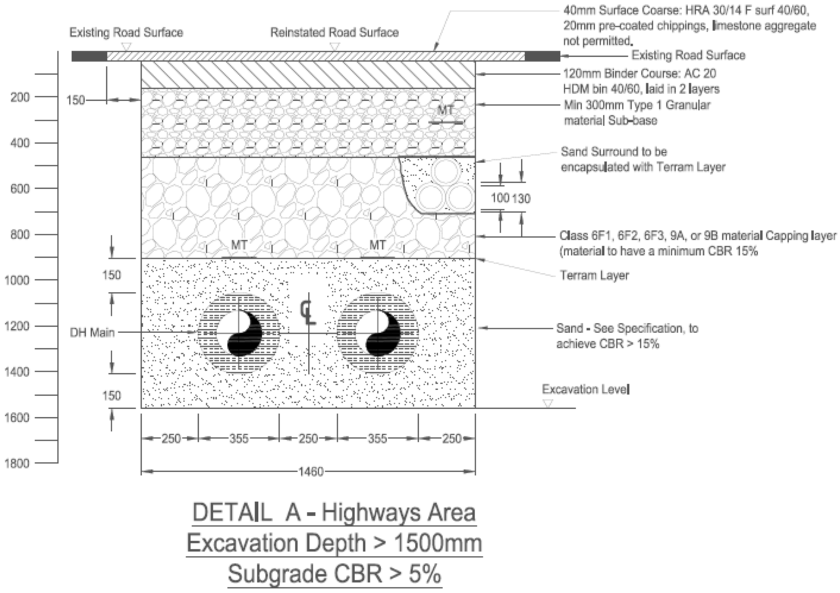

Figure 23: Drawing Example – Trench detail

Target Depth Analysis

Target Depth analysis for trench excavation worked well in terms of a cost effective method of establishing complex areas, HAZIDS and general depths. The process allows for cost effective depth analysis in detailed design and has been adopted by other consultants in the industry following the success of this project

Controls Strategy

The Controls strategy has been designed for replication and expansion into the network. All hardware has been specified to be on open protocols to be easily integrated into Building Management Systems (BMS) or other platforms such as 'Bristol is Open'.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

13.5 Impact on SME´s

The contractor on the main pipe works funded by the project was an SME and a relatively new entrant to the market. The company was formed by combining an experienced civils contractor with another small organisation that had experience in the mechanical side of steel pipe installations.

In terms of financial impact the project's cost were over half of the previous year's turnover. While this presented a medium risk to BCC as a client at tender stage, the project's success has put the organisation in a good position for strong and positive growth in the current year.

In addition to this the company has been able, through the collaborative working and contracting method to develop the Quality Assurance methods and testing procedures to a higher standard. This is a real positive outcome for the company and Bristol as it meets one of our additional aims for the industry as we continue to build out the network.

The company has also been supported throughout the project team in the administration of the project and how to use the NEC contract processes as project management tools. In particular the contractor's management team have learnt how to develop and update a detailed and compliant programme of works. This not only assists tracking the progress of the project but ensures easy administration of costs for delays or addition of time for required changes in design and scope where required.

The phased array testing has also been introduced due to the REPLICATE project and is being adopted by the company as its standard weld testing procedure.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

14. CONCLUSIONS

In conclusion this project has seen success in the contracting and construction phases maintaining high quality through collaborative working across the project team. The project has been planned and elements designed to fit with the future smart city, but without over reaching the current capabilities of the city or the technology available.

It is worth noting that the current timeline means that the project is not yet finished and Bristol has more work to do in collecting data and analysing it to assess the full impact of the project on this city, this will be completed in the next 2 years and reported on in a later document.

The main successes and learning have been:

- The correct choice of contract for this type of project that has maintained value for money while driving up standards and quality.
- The introduction of Phased array Ultrasonic Testing (PAUT) into the industry raising the quality assurance of welding practices with District heating.
- This introduction of a new design methodology, target depth analysis which reduces costs in the design phase while maintain the level of information rehired to enable contractors to de-risk and plan ahead to navigate complex underground environments
- Provision of a standard suite of tendering and contract documents that will save time and cost for future phases of Bristol's heat network build out.
- Provision of a monitoring and data strategy that can be easily replicated and expanded on as new elements of the Heat network are connected.
- Future proofing of all of the controls so that when the network is fully operational, a balance between carbon factor, cost and heat demand can be found to ensure the network is not only viable in terms of finances but also in terms of driving down heating costs for the some of the city's poorest and most vulnerable residents, thus reducing fuel poverty while also seeking to reduce the amount of CO_2 emitted in order to produce the required heat demand.