OPDC
OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Utilities Study

Appendices G to M

2017

MAYOR OF LONDON

Appendix G Technology Cost and Carbon Saving Comparison

G.1 Introduction

As part of the process of developing an energy strategy for proposed development in the Old Oak area, AECOM has compared carbon emission outcomes and costs for a range of energy strategy options that could be applied. The energy strategy options focus particularly on ways of reducing heat demand and supplying the remaining demand from low carbon heat sources. Key strategic questions at this stage relate to the performance and hence role of heat networks in enabling long term carbon emission savings compared to the counterfactual 'default London Plan-compliant' approach (see Box G.**1** in section G.2.2.3).

AECOM analysed 34 'Technology scenarios' and calculated the average carbon emissions of homes in each of five time periods through to full build-out and under three grid electricity decarbonisation scenarios. The assumptions and methodology for the carbon analysis, the resulting average carbon emission outcomes, capital and running cost estimates for selected technology scenarios, and a synthesis of performance metrics combining carbon emission, capital cost and running cost outcomes for the range of technical scenarios are set out in the remainder of this note in the following sections:

- G.2 Specification of Energy Technology Modelling Scenarios;
- G.3 Carbon Emissions of Technology Scenarios;
- G.4 Costs; and
- G.5 Synthesis of Carbon and Cost Results;

G.2 Specification of Energy Technology Modelling Scenarios

This section sets out assumptions about proposed development at Old Oak and key specifications for the range of technology options evaluated for saving energy and carbon in homes.

G.2.1 Development Area & Context

G.2.1.1 Grid Decarbonisation Trajectory

The periods used for the carbon analysis were heavily influenced by the need to understand the effect of grid decarbonisation on the carbon emissions of alternate technical options. The grid is projected to decarbonise rapidly through the 2020s and early 2030s and then more slowly to the end of the analysis period. As such, it was important to look at carbon outcomes over short (5-year) periods during the stage of rapid decarbonisation. The time periods used in the carbon analysis, and the average grid electricity emission factors over those time periods under three grid decarbonisation scenarios, are set out in Table G.2.1.

Emission factors for grid electricity								gCO$_2$/kWh
	Source projections				**Scenario projections**			
	[Average]		[Marginal]	[Marginal + tech-specific]		Decarbonisation		Sensitivities
						Slower	**Faster**	**Gas CHP**
Year	TGB Supplementary: Domestic electricity	SAP 2012 + SAP 2016 Consultation: 3-year average	TGB Supplementary: Domestic electricity	DECC Bespoke: 50% export, 50% used on site	**Period**	All electricity		Displaced
2016	**383**	**519**	**324**	**368**	**Current**	**519**	**-**	**-**
2017	328	399	314	374				
2018	317	399	304	380				
2019	298	302	294	372	2017 - 20	351	302	367
2020	265	302	282	359				
2021	234	302	270	362				
2022	215	229	258	391				
2023	183	229	245	351	2021 - 25	234	201	339
2024	192	229	231	359				
2025	180	183	216	354				
2026	160	183	200	361				
2027	159	183	184	354				
2028	133	133	167	331	2026 - 30	153	136	320
2029	116	133	148	326				
2030	112	133	129	305				
2031	106		118	309				
2032	100		107	298				
2033	86		98	292	2031 - 35	89		304
2034	85		89	280				
2035	71		81	279				
2036	69		74	284				
2037	60		68	281				
2038	54		62	279				
2039	55		56	275				
2040	51		51	271				
2041	46		46	267				
2042	45		45	273				
2043	40		40	271	2036 - 50	43		270
2044	35		35	264				
2045	36		36	264				
2046	33		33	264				
2047	30		30	264				
2048	31		31	264				
2049	28		28	264				
2050	28		28	264				

Notes: Red numbers – derivation of these values involved extrapolation of the underlying data sources.

Table G.2.1. Time Periods and Corresponding Grid Emission Factors (3 Scenarios) Used for Carbon Analysis

G.2.1.2 Phasing Trajectory

As agreed with OPDC, AECOM made assumptions about the build-out rate for dwellings based on the ‘DRAFT Phasing Trajectory v7.11 Early Scenario for Planning’. Under this trajectory, development occurs from 2017 to 2047, inclusive. For the carbon emissions analysis, this trajectory was broken down into periods (see Table G.2.1), aligned as far as possible with the development phases identified and used for other ongoing studies.

The quantum of development projected to come forward in each period (based on the ‘DRAFT Phasing Trajectory v7.11 Early Scenario for Planning’) is set out in Table G.2.2.

Period	Affordable for Rent Units [no.]	Private Homes Units [no.]	Total Units [no.]	Total Units [%]	Net Office Floor Area [m^2]
2017 - 20	1,112	1,112	2,224	8.2%	14,999
2021 - 25	2,761	2,761	5,521	20.5%	27,869
2026 - 30	2,954	2,954	5,907	21.9%	195,776
2031 - 35	3,032	3,032	6,064	22.5%	321,601
2036 - 50	3,626	3,626	7,251	26.9%	253,779

Table G.2.2. Development Quantum Assumed in Each Time Period

G.2.1.3 Built Form

Based on the information provided through various meetings with OPDC and supported by the OPDC interactive model and map[1], it is assumed for the purpose of this evaluation that the average block height across Old Oak is 10 storeys, ranging up to 25 storeys.

Figure G.2.1. Typical Residential Block Forms within OPDC Interactive Model

Analysis of multiple existing developments of varying densities has been conducted based on previous AECOM schemes. A total of 4 developments were selected, based on the development density, as representatives of the proposed Old Oak development. The accommodation schedules were consulted for the 4 selected developments and the average number of dwellings per floor was calculated for each block in the development. An average of 12 units per storey, approximately 920 m^2 Gross Internal Area (GIA) per storey, was assumed based on these representative developments.

G.2.1.4 Scales of Technology Implementation

For most technologies, the scale of implementation affects the capital costs. For some technologies, the scale of implementation also changes assumptions about technical performance (e.g. efficiency; the area available to locate equipment, and hence the maximum installable capacity and proportion of demand met; etc.). Four implementation scales were identified as a basis for considering the effects of scale on carbon outcomes and costs:

- Unit – individual homes,
- Block – a discrete apartment block,

[1] Available at https://www.london.gov.uk/about-us/organisations-we-work/old-oak-and-park-royal-development-corporation-opdc/about-opdc/opdc-2

- Development site – multiple blocks, and
- Cluster / area-wide – the broad areas making up the Old Oak area as a whole (North Acton, Willesden Junction, HS2, Old Oak North, and Scrubs Lane).

G.2.1.5 Typical Blocks

The 'block' scale of implementation is the one that imposes most constraints on the application and performance of technologies. The size of the roof constrains the potential for roof-mounted PV and solar hot water collectors, and the size of the plot constrains the ground area available for the borehole field of a closed loop ground source heat pump system. The most relevant characteristics of the typical block are set out in Table G.2.3.

Storeys	Units per floor	Units	Unit GIA per floor [m^2]	GIA as % of GEA	Roof area [m^2]	Plot area [m^2]
10	12	120	920	90%	1,022	1,200
Notes: GIA = gross internal area; GEA = gross external area, which is assumed to be equal to both the roof area (when calculating area available for solar technologies) and building footprint (from which the plot area available for the ground loop supplying ground source heat pumps is calculated).						

Table G.2.3. Typical Block Characteristics

Assuming an average storey height of 10 storeys, the typical block at Old Oak will consist of 120 units of 9,200 m^2 GIA.

G.2.1.6 Typical Development Site

It is assumed a typical representative development plot could consist of 4x10 storey buildings and a single 25 storey building. The energy demands and carbon emissions of homes are influenced by whether they are single or dual aspect. A ratio of 65:35 single to dual aspect dwellings was assumed for a site. Based on these assumptions, each development site consists of:

- 780 units (approximately 59,800 m^2);
- 507 single aspect units;
- 273 dual aspect units;
- 60 ground floor units; and
- 60 top floor units.

The above unit breakdown is combined with the unit sizes (in number of bedrooms) to produce a set of unit type combinations (1-/2-/3-/4-/5-bed, ground-/mid-/top-floor, and single/dual aspect) for modelling. Each unit type will have different regulated heating and electrical demands to be calculated using representative models.

G.2.1.7 The Old Oak Area and Development Clusters

It is understood that the Old Oak masterplan will be made up of 5 main development clusters: North Acton, Willesden Junction, HS2, Old Oak North, and Scrubs Lane.

A total of 26,967 homes and ~814,000 m^2 of non-domestic area are assumed to be served by the area wide heating network.

G.2.1.8 Unit Mix and Sizes

The carbon analysis assumes that the homes delivered will be a mix of 1- to 5-bed flats. The mix for affordable housing is built up from the observed mix of units offered for 'social rent', 'London Living rent', and 'shared ownership', assuming a given proportion (see Table G.2.4) of homes of each tenure type. The mix for market housing assumes 'Local Market Delivery'. The unit size assumptions are taken from the London Housing Design Guide, Minimum space standards for new dwellings. The unit mix and sizes used in the carbon analysis are summarised in Table G.2.4.

Bedrooms	Social Rent	London Living Rent	Shared Ownership	Affordable Housing	Market Housing	GIA [m^2]
1	23%	3%	19%	**14%**	**30%**	**50**
2	28%	25%	35%	**28%**	**50%**	**70**
3	34%	47%	33%	**40%**	**16%**	**86**
4	11%	19%	10%	**14%**	**4%**	**99**
5	4%	6%	3%	**5%**	**0%**	**112**
% of total	43.33%	43.33%	13.33%	**50%**	**50%**	

Table G.2.4. Unit Mix and Sizes

G.2.2 Technology Scenarios

G.2.2.1 Technology Scenario Characteristics

The technology scenarios are defined in terms of the characteristics set out in Table G.2.5.

Scenario characteristic	Options
Fabric and services specification	London Plan (LP); or Advanced Fabric (AF)
Heat network (DHN) flow and return temperatures	High – 85°C flow / 55°C return; or Low – 70°C flow / 40°C return
Fuel type of lead heat generator	Grid electricity with heat pump; direct grid electricity; waste; or gas
Lead heat generator / source and corresponding generator efficiencies	Electric storage / convection heaters; electric boilers; heat pumps- exhaust air heat recovery, ground, air, water (open loop ground), canal, or sewer source; Powerday (off-site bulk heat from waste); gas boilers; or gas-fired CHP.
Peak load heat generator / source	Direct electric secondary heating; electric boiler; gas boiler; Powerday*
Supplementary heat demand reduction	Solar hot water heating (where compatible)**
Bolt-on	Photovoltaics (where compatible)***

Notes:

* Some scenarios consider very high (70%) proportions of heat from Powerday with very low (e.g. 5%) proportions from typical peak load gas (or alternatively electric) boiler plant – in those cases, the assumption is that heat from Powerday meets a significant share of peak heat loads.

** Solar hot water was included in some technology scenarios suited to block and unit scale implementation, where it would not displace heat network base load, and when a solar thermal system was considered compatible with the main heating system.

*** Apart from competition for roof space (with solar thermal), there is no interaction between PV and the other carbon saving technologies considered. PV could be applied as a 'bolt-on' to all technology scenarios except those with solar hot water heating. The carbon savings from PV and capital costs can be considered independently of the technology scenarios.

Table G.2.5. Technology Scenario Characteristics

G.2.2.2 Technology Scenarios Evaluated

The full set of scenarios for which analysis was undertaken is set out in Table G.2.6. (For further details on assumed system efficiencies see Table G.2.7, and for proportions of heat from all heat sources see Table G.3.1.)

TS no.	Technology Scenario	Fabric & services spec.	Scenario Description	DHN flow/ return	Lead heat generator type
1	LP CHP-60 High Temp	London Plan	gas CHP (60%, η elec = 36%) + gas boiler, high temp network	85/55	gas-fired
2	LP CHP-60 Low Temp	London Plan	gas CHP (60%, η elec = 36%) + gas boiler	70/40	gas-fired
3	LP DE Storage Heater	London Plan	electric storage / convection heater	n/a	direct electric
4	LP DE Storage Heater SHW	London Plan	electric storage / convection heater + solar hot water	n/a	direct electric
5	LP GSHP Gas Boiler	London Plan	ground source heat pump (60%) + gas boiler	70/40	heat pumps
6	LP GSHP Gas Boiler SHW	London Plan	ground source heat pump (60%) + boiler + solar hot water	70/40	heat pumps
7	LP GSHP ASHP	London Plan	ground source heat pump (60%) + air source heat pump	70/40	heat pumps
8	LP GSHP ASHP SHW	London Plan	ground source (60%) + air source heat pump + solar hot water	70/40	heat pumps
9	AF CHP-60 High Temp	Advanced	gas CHP (60%, η elec = 36%) + boiler, high temp network	85/55	gas-fired
10	AF CHP-60 Low Temp	Advanced	gas CHP (60%, η elec = 36%) + gas boiler	70/40	gas-fired
11	AF DE Storage Heater	Advanced	electric storage / convection heater	n/a	direct electric
12	AF DE Storage Heater SHW	Advanced	electric storage / convection heater + solar hot water	n/a	direct electric
13	AF GSHP Gas Boiler	Advanced	ground source heat pump (60%) + gas boiler	70/40	heat pumps
14	AF GSHP Gas Boiler SHW	Advanced	ground source heat pump (60%) + gas boiler + solar hot water	70/40	heat pumps
15	AF GSHP ASHP	Advanced	ground source heat pump (60%) + air source heat pump	70/40	heat pumps
16	AF GSHP ASHP SHW	Advanced	ground source (60%) + air source heat pump + solar hot water	70/40	heat pumps
17	AF HRHP	Advanced	exhaust air heat recovery heat pump	n/a	heat pumps
18	AF HRHP SHW	Advanced	exhaust air heat recovery heat pump + solar hot water	n/a	heat pumps
19	LP 5xCluster CHP-70, Low Temp	London Plan	gas CHP (70%, η elec = 39%) + gas boiler	70/40	gas-fired
20	LP Pwrdy-70 + CHP-15	London Plan	Powerday (70%) + gas CHP (15%, η elec = 39%) + gas boiler	70/40	waste-fired
21	LP Pwrdy-55 + CHP-35	London Plan	Powerday (55%) + gas CHP (35%, η elec = 39%) + gas boiler	70/40	waste-fired
22	LP Pwrdy-40 + CHP-35	London Plan	Powerday (40%) + gas CHP (35%, η elec = 39%) + gas boiler	70/40	waste-fired
23	LP Pwrdy-70 + HPs-10 + CHP-15	London Plan	Powerday (70%) + heat pump (10%) + gas CHP (15%) + gas boiler	70/40	waste-fired
24	LP Pwrdy-55 + HPs-20 + CHP-15	London Plan	Powerday (55%) + heat pump (20%) + gas CHP (15%) + gas boiler	70/40	waste-fired

TS no.	Technology Scenario	Fabric & services spec.	Scenario Description	DHN flow/ return	Lead heat generator type
25	LP Pwrdy 40 + HPs-30 + CHP-15	London Plan	Powerday (40%) + heat pump (30%) + gas CHP (15%) + gas boiler	70/40	waste-fired
26	LP Pwrdy 70 + HPs-10 +DEB	London Plan	Powerday (70%) + heat pump (10%) + electric boiler	70/40	waste-fired
27	LP Pwrdy 55 + HPs-20 +DEB	London Plan	Powerday (55%) + heat pump (20%) + electric boiler	70/40	waste-fired
28	LP Pwrdy 40 + HPs-30 +DEB	London Plan	Powerday (40%) + heat pump (30%) + electric boiler	70/40	waste-fired
29	LP Gas Boiler	London Plan	gas boiler	70/40	gas-fired
30	LP DE Boiler	London Plan	electric boiler	70/40	direct electric
31	LP GSHP DE Boiler	London Plan	ground source heat pump (60%) + electric boiler	70/40	heat pumps
32	LP ASHP Gas Boiler	London Plan	air source heat pump (60%) + gas boiler	70/40	heat pumps
33	LP ASHP DE Boiler	London Plan	air source heat pump (60%) + electric boiler	70/40	heat pumps
34	AF GSHP DE Boiler	Advanced	ground source heat pump (60%) + electric boiler	70/40	heat pumps

Notes: LP = London Plan 'compliant' fabric; AF = advanced fabric; SHW = solar hot water heating; DE(B) = direct electric (boiler); η = efficiency; GSHP = ground source heat pumps; ASHP = air source heat pumps; HRHP = exhaust air heat recovery heat pump

Table G.2.6. Technology Scenarios Analysed

G.2.2.3 Counterfactual

A common, static, baseline was used to assess the carbon intensity and financial costs for applying each of the energy technologies. The carbon savings and cost uplifts are the difference from this baseline on a per unit basis.

The baseline is defined as a home with a London Plan compliant specification that has its space heating and domestic hot water requirement delivered via a high temperature heat network (85°C flow 55°C return) served by gas-fired CHP engines providing 60% of annual heat demand, with peak load gas boilers providing 40% of heat demand. A distribution loss factor of 1.3 is assumed based on primary network heat losses – between the heat generation plant and the heat substation at the development plot boundary – of 10% and 15% losses in the secondary heat network between the substation and the heat interface unit in the homes. 91% efficient gas fired boilers provide the remaining heat for the development site scenario.

- Buildings designed to meet Building Regulations Criterion 1 through energy efficient fabric and fixed services alone;
- Development-wide heat networks for each site that comes forward for planning served by gas-fired CHP housed in a central energy centre;
- Roof-mounted photovoltaics to bring on-site carbon savings to at least 35%, if required, or to the extent possible given space constraints on locations for PV panels (N.B. the counterfactual used in the evaluation assumes that **PV is NOT currently required to meet 35% on site savings** when 60% of heat is supplied by gas CHP); and
- Offsetting of residual carbon emissions off site, directly by the developer or via payment into an offset fund at the rate established by the local planning authority.

Box G.1. Counterfactual 'default London Plan-compliant' energy strategy

This counterfactual is represented by TS no. 1 in the list of technology scenarios evaluated and the ‘Development’ level of technology application in Table G.2.7.

G.2.2.4 Efficiency of Energy Technology Options

The appraisal considered technology options applied at 4 scales:

- Area level – district heat networks connecting the 5 Old Oak clusters;
- Development level – communal heat networks serving multiple buildings on a development site;
- Block level – communal heating within a single block;
- Unit level – each unit is served by an individual heating system.

Each option was modelled for two levels of fabric and services specifications: (i) London Plan compliant, and (ii) advanced fabric specification.

The table below shows the coefficients of performance for the technologies applied at each scale.

<table>
<tr><th rowspan="2">Technology</th><th></th><th colspan="4">Coefficient of performance</th></tr>
<tr><th>Level</th><th>Area</th><th>Development</th><th>Block</th><th>Unit</th></tr>
<tr><td colspan="2">Powerday</td><td>heat*</td><td rowspan="4" colspan="3">n/a</td></tr>
<tr><td colspan="2">Canal heat pump</td><td>2.80</td></tr>
<tr><td colspan="2">Sewer heat pump</td><td>3.30</td></tr>
<tr><td colspan="2">Open loop borehole heat pump</td><td>3.10</td></tr>
<tr><td colspan="2">Closed loop borehole heat pump</td><td colspan="2">n/a</td><td>3.10</td><td rowspan="3">n/a</td></tr>
<tr><td colspan="2">Gas CHP</td><td>$0.39_{electical}$ ($0.38_{thermal}$)</td><td>$0.36_{electrical}$ ($0.42_{thermal}$)</td><td>n/a</td></tr>
<tr><td colspan="2">Gas boilers</td><td colspan="3">0.91</td></tr>
<tr><td colspan="2">Direct electric boilers</td><td colspan="3">1.00</td><td>n/a</td></tr>
<tr><td colspan="2">Air sourced heat pump</td><td colspan="2">n/a</td><td colspan="2">2.90</td></tr>
<tr><td colspan="2">Solar hot water</td><td colspan="2">n/a</td><td colspan="2">heat**</td></tr>
<tr><td colspan="2">Direct electric storage</td><td colspan="3">n/a</td><td>1.00</td></tr>
<tr><td colspan="2">Exhaust Air Heat recovery heat pump</td><td colspan="3">n/a</td><td>3.30</td></tr>
<tr><td colspan="6">Notes:
* Powerday is assumed to supply bulk heat. The efficiency of generating plant is reflected in the carbon intensity assumed for the heat supplied.
** The performance of solar hot water heating is accounted for in the SAP modelling and results in a reduction in residual hot water demand to be met by the other systems fitted to meet hot water demand.</td></tr>
</table>

Table G.2.7: Coefficients of Performance (Efficiencies) for Heating Technology Options

Scale of application of technology options has effects beyond efficiency, which are discussed in turn below.

G.2.2.5 Capacity of Area-level Heat Sources

It is assumed that area level solutions are based on a district heat network. Table G.2.8 sets out the assumed capacity of the heat sources for the options evaluated.

Heat Source	Capacity available (MW)
Grand Union Canal serving heat pumps	1 – 3 MW varies seasonally
London aquifer serving heat pumps	5 no. 1.2 MW open loop boreholes = 6 MW
Sewage network serving heat pumps	5 no. 200m installations = 1 – 3 MW
Powerday Energy from Waste	3 – 10 MW
Total	**11 – 22 MW**

Table G.2.8. Summary of Recommended Heat Sources for Area Level Network

G.2.2.6 Area-level Heat Mix Scenarios

Three illustrative heat mix scenarios have been chosen to represent possible outcomes for heat sources for an area wide network. The scenarios are titled based on the lead heat source in the heat mix, as follows:

G.2.2.6.1 Gas CHP

A gas CHP area wide network was modelled to represent the CO_2 emissions that would likely occur for larger sites such as Car Giant if OPDC left delivery to the market and no intervention is made by OPDC. An area wide gas CHP network is also what was assumed in the GLA decentralised energy study that formed the basis of the evidence base for the draft Regulation 18 consultation for the Local Planin February 2016[2].

It is assumed that gas CHP would meet the full baseload with gas boilers providing peak. For this scenario the higher temperature network 85^{o}Cflow 55^{o}C return is assumed. Heat losses are assumed to be 10% in the primary and 15% in the secondary network with a distribution loss factor of 1.3. 70% of heat is assumed to be provided from the CHP and 30% from gas boilers.

G.2.2.6.2 Powerday

The Powerday recycling facility situated in Old Oak is considering installing energy from waste equipment to enable cogeneration on the site. Based on the availability of refuse derived fuels and solid refuse fuels on site a number of capacity options are currently being considered by Powerday (up to 5.7 MW_e) providing a potential opportunity to serve the Old Oak scheme with heat. This could potentially be increased to 10MW based on the volume of SRF currently being produced on site (approx. 100,000 tonnes per year).

The heat supplied from a potential Energy from Waste (EfW) facility has been modelled using a fuel carbon factor of 0.047gCO_2/kWh for the first ten years (SAP 2012 figure) then 0.074gCO_2/kWh for the remaining period (proposed SAP 2016 figure). It is estimated that 10MW_{th} could be available for the network. Any shortfalls occurring between the assumed EfW supply and the peak demand is assumed to be made up with gas CHP for baseload and gas boilers for peak in line with efficiency and carbon factor outlined in table 2. All top up gas boilers are assumed to have an efficiency of 91% in line with the London Plan guidance for the calculation of a site emission baseline. The resulting heat spilt serving an area wide network at full build out with a baseload demand of 20MW has been assumed to be 25% gas boilers, 40% Powerday heat and 35% gas CHP. The carbon savings for a range of heat splits have been modelled to test the impacts on CO_2 emissions of transitioning to different energy supply options over the development cycle as grid emissions fall.

The distribution network is assumed to be designed efficiently and to have a lower distribution temperature than the base case with flow of 70^{o}C and return of 40^{o}C. 70^{o}C flow will enable the system to serve both space heating and hot water. It is assumed that low temperature distribution systems are installed in all new buildings i.e. underfloor heating systems in homes. A loss factor of 1.2 is assumed, this equates to primary losses of 8% and secondary losses of 10 %.

[2] Old Oak Decentralised Energy Strategy. Local Plan Supporting Study. Draft for Regulation 18 Consultation. 4th February 2016.

G.2.2.6.3 Powerday + Heat Pumps + Gas CHP

In this option, the district heat network is served by a combination of heat sources including up to 10MW from Powerday, 9MW from heat pump energy technologies (based on notionally 1.5MW from the canal, 1.5MW from 5No sewer installations and 6 MW from 5No open loop boreholes). And up to 5MW from Gas CHP engines which would be used to improve revenue from system balancing mechanisms and provide a back-up baseload supply. Any shortfalls between the baseload assumed supply and the peak demand is assumed to be made up with gas boilers.

The assumption has been made that at full build out 15% of heat would be provided from gas boilers, 30% from Powerday, 40% from heat pumps and 15% from gas CHP. The carbon savings for a range of alternative heat splits have been modelled to test the impacts on CO_2 emissions of transitioning to different energy supply options over the development cycle as grid emissions fall.

This scenario is intended to represent multi source heat network being operated both to maximise carbon savings but also designed to enable operators to maximum revenue streams in a more dynamic electricity market with varying price signals designed to manage demand and supply.

The distribution network is assumed to be designed efficiently and to have a lower distribution temperature than the base case with flow of 70^{o}C and return of 40^{o}C. This will enable the system to serve both space heating and hot water. It is assumed that low temperature distribution systems are installed in all new buildings i.e. underfloor heating systems in homes. A loss factor of 1.2 is assumed, this equates to primary losses of 8% and secondary losses of 10 %.

G.2.2.7 Block Level Energy Technology Scenarios

Block based solutions could be delivered as an alternative to supplying buildings with heat from area wide or development scale heat networks. The following technologies were modelled with both London Plan ‘compliant’ and advanced fabric insulation standards to explore costs and carbon savings.

G.2.2.7.1 Solar Hot Water Heating

The impact of adding solar (thermal) water heating was modelled for each of the main heating/hot water options, i.e. heat pump and direct electric systems. It is assumed that block based systems will have communal domestic hot water and space heating systems linked to a heat interface unit/meter in each flat. Energy savings were modelled based on the maximum collector area of evacuated tube solar water heating that can be accommodated within the typical block, assumed to be 25% of the roof area. Evacuated tube collectors were assumed to maximise output from the available roof area (that could otherwise accommodate PV).

G.2.2.7.2 Ground Source and Air Source Heat Pumps

For ground source systems, a closed ground loop linked to heat pumps providing as much of the space heating and hot water as possible was assumed, with space heating provided by underfloor heating systems. Separate capacity analysis of the ground loop was undertaken to provide confidence that the assumed proportion of heat and hot water supplied is reasonable. This considered the maximum closed loop system that could be delivered within the footprint of the typical block.

G.2.2.7.3 PV

PV was treated as a ‘bolt-on’ option as it does not interact with any other aspect of the technology scenarios. Potential carbon savings from PV and related costs are considered separately from the results of the technology scenarios.

G.2.2.8 Unit Level Energy Technology Scenarios

G.2.2.8.1 Direct Electric Heating

This scenario was modelled as modern, slimline combined storage + convection heaters with CELECT-type control. The system efficiency for this scenario was the default value in SAP 2012. Local hot water storage with large (at least 210 litres) storage was assumed with direct electric immersion heaters with Economy 7 controls. This option is intended to assess the carbon implications of what would be a very low cost option that is also a low carbon option once the grid has substantially decarbonised.

G.2.2.8.2 Exhaust Air Heat Pump

This system was modelled with the advanced fabric specification only. Residual space heating required is delivered through a heating coil in the whole house mechanical ventilation system. It is assumed that an ASHP would be used to serve the domestic hot water using exhaust air as its heat source. System assumptions for this scenario were a COP of 3.3, a programmer for system control, and local hot water storage cylinders in each home.

G.2.2.8.3 Solar Hot Water Heating

For both the options above the effect of adding solar thermal to serve the hot water demands of approximately 23% of units (homes on the top three floors, also capped by available collector area) was tested. Solar water heating would serve dual coil cylinders, with top up from direct electric immersion heater or exhaust air heat pump (respectively for the technology scenarios above).

G.2.3 Cooling

Under projected climate conditions and at the development densities proposed in the Old Oak area, the design of homes should consider likely demands for active cooling to prevent summer overheating.

AECOM considered whether there is a potential role for cooling networks. As with heat network, a cooling network will only be viable where there is a high and consistent (over the year) demand density, such as in a concentrated commercial zone. AECOM judges that homes, even at high density with some mix of commercial uses, will not provide the cooling demand density necessary to justify a wide area cooling network. As such, it is assumed that any cooling would be provided at a block or individual unit level.

Active cooling in buildings is generally delivered via some form of heat pump. While the efficiencies of heat pumps – and hence carbon intensity – do vary depending on the heat source (air, ground, groundwater, canal water), the differences are not as significant as those between alternative heating sources and fuels (gas, direct electric, electric via heat pumps, heat from waste). It is likely that differences due to detailed design and specification (i.e. between choosing typical and best in class equipment) would have as much influence on carbon outcomes as differences due to system type. As such, in carbon terms, AECOM concluded that the effect of adding cooling would be broadly the same across all of the technology scenarios considered in this report.

Given the considerations above, it can be seen that cooling provision is not a key factor in the choice of energy strategy, which will principally revolve around the choice of building fabric and lead heat source(s). The only effect of any cooling provision on infrastructure will be considerations relating to seasonal peak electricity demands. As with PV, cooling can be considered a ‘bolt-on’ to whichever preferred energy strategy emerges.

G.3 Carbon Emissions of Technology Scenarios

G.3.1 Calculation of Current and Projected Carbon Emissions for Technology Scenarios

G.3.1.1 SAP Modelling to Determine Dwelling Energy Demands

To fully reflect the benefits of energy efficient underlying fabric and services design for dwellings, it is preferable to model real designs as similar as possible to those that are anticipated in a development under study. Dwelling designs prepared specifically for developments in the Old Oak area were not available, so flat designs from schemes recently submitted for planning in London, and for which AECOM had existing SAP model data, were selected as proxies. Ideally proxy designs would have been selected for each size of dwelling (where size is synonymous with number of bedrooms, as per Table G.2.4), and covering the nine configurational combinations of:

- Single aspect and two dual aspect units – one with main glazing facing east and the other west; and
- Ground-, mid- and top-floor units.

However, the available set of designs and models did not include enough 4- and 5-bed flats to make up a representative mix of models for those unit sizes. As such, AECOM modelled the nine configurational combinations for each of 1-, 2-, and 3-bed flats only – making a total of 27 combinations of dwelling size and configuration per technical scenario to be modelled. 4- and 5-bed flats were then assumed to have the same per-square-metre underlying annual energy demands as 3-bed flats. (A spot check using available results from past modelling of 4/5-bed flats suggested that the error involved in this assumption was small – it tends to over-estimate demands, but by <5% in the cases checked.)

AECOM undertook SAP modelling for this study using NHER Plan Assessor, which is approved SAP modelling software for the purposes of demonstrating compliance with Building Regulations Part L 2013. The use of approved SAP software is essential to establishing the correct underlying heat and electricity demands of a dwelling. The dwelling (carbon) emission rates then depends on assumptions about heat generator efficiencies and (for block heating or heat networks) heat source mix, CHP electrical efficiency, and distribution losses. Once the underlying demands are known, and given a heat splits, generator efficiencies, etc., calculating the dwelling emission rate is relatively straightforward and can be done without SAP software. Using a spreadsheet to calculate dwelling emission rates makes it easier to look at outcomes for a range of heat source mixes and generator efficiencies, which change the carbon emissions but do not change the underlying energy demands of a dwelling. Calculations outside approved SAP software are also the only way to investigate the effects of changing fuel emission factors over time.

Technical scenarios 1 to 18 in Table G.2.6 were modelled using SAP to determine underlying energy demands and current (Part L 2013) dwelling emission rates. Individual energy demands (per square metre) for the 27 unit types modelled were converted into weighted average demands (per square metre) for 1-, 2-, and 3-bed units based on the number of units of each configuration that would be present in the typical block (see section G.2.1.8).

G.3.1.2 Post-processing to Determine Current and Future Carbon Emissions

AECOM developed a post-processing spreadsheet that calculated dwelling emission rates, starting from appropriate demands established from the first 18 SAP models and applying the heat source mix and generator efficiencies corresponding to the technical scenario definition. The algorithms implemented in the post-processing spreadsheet were based on the DER worksheet set out in the SAP Technical Manual[3] and validated using the dwelling emission rate results for technical scenarios 1 – 18 from NHER Plan Assessor.

Results for future time periods for the first 18 technology scenarios were post processed. Carbon emissions for technical scenarios 19 and onward were entirely 'post-processed' Carbon emissions for future time periods were post-processed for all technical scenarios, based on the projected emission factors set out in Appendix F 'Technical Note – Carbon emission factors'.

[3] SAP 2012 version 9.92 (October 2013)

The main heat source mixes and communal system factors for each technology scenario, which represent the main inputs for the post-processing to calculate dwelling emission rates (in addition to the efficiencies set out in Table G.2.7), are set out in Table G.3.1.

Technology scenario		Fraction of space heat from system									Comm. Sys. factors		
		Secondary	Community	Main system or CHP	Gas boiler	Open loop GSHP	Canal source HP	Sewer source HP	Powerday	Electric boiler	Space heating control / charging	Hot water control	Distribution loss
1	LP CHP-60 High Temp	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.30
2	LP CHP-60 Low Temp	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
3	LP DE Storage Heater	15%	85%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
4	LP DE Storage Heater SHW	15%	85%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
5	LP GSHP Gas Boiler	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
6	LP GSHP Gas Boiler SHW	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
7	LP GSHP ASHP	0%	100%	60%	0.00%	40%	0%	0%	0%	0%	1.05	1.00	1.20
8	LP GSHP ASHP SHW	0%	100%	60%	0.00%	40%	0%	0%	0%	0%	1.05	1.00	1.20
9	AF CHP-60 High Temp	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.30
10	AF CHP-60 Low Temp	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
11	AF DE Storage Heater	15%	85%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
12	AF DE Storage Heater SHW	15%	85%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
13	AF GSHP Gas Boiler	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
14	AF GSHP Gas Boiler SHW	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
15	AF GSHP ASHP	0%	100%	60%	0.00%	40%	0%	0%	0%	0%	1.05	1.00	1.20
16	AF GSHP ASHP SHW	0%	100%	60%	0.00%	40%	0%	0%	0%	0%	1.05	1.00	1.20
17	AF HRHP	0%	100%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
18	AF HRHP SHW	0%	100%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
19	LP 5xCluster CHP-70, Low Temp	0%	100%	70%	30%	0%	0%	0%	0%	0%	1.05	1.00	1.20
20	LP Pwrdy-70 + CHP-15	0%	100%	15%	15%	0%	0%	0%	70%	0%	1.05	1.00	1.20
21	LP Pwrdy-55 + CHP-35	0%	100%	35%	10%	0%	0%	0%	55%	0%	1.05	1.00	1.20
22	LP Pwrdy-40 + CHP-35	0%	100%	35%	25%	0%	0%	0%	40%	0%	1.05	1.00	1.20
23	LP Pwrdy-70 + HPs-10 + CHP-15	0%	100%	15%	5%	10%	0%	0%	70%	0%	1.05	1.00	1.20
24	LP Pwrdy-55 + HPs-20 + CHP-15	0%	100%	15%	10%	10%	5%	5%	55%	0%	1.05	1.00	1.20
25	LP Pwrdy 40 + HPs-30 + CHP-15	0%	100%	15%	15%	15%	8%	7%	40%	0%	1.05	1.00	1.20
26	LP Pwrdy 70 + HPs-10 +DEB	0%	100%	0%	0%	10%	0%	0%	70%	20%	1.05	1.00	1.20

Technology scenario		Fraction of space heat from system									Comm. Sys. factors		
		Secondary	Community	Main system or CHP	Gas boiler	Open loop GSHP	Canal source HP	Sewer source HP	Powerday	Electric boiler	Space heating control / charging	Hot water control	Distribution loss
27	LP Pwrdy 55 + HPs-20 +DEB	0%	100%	0%	0%	10%	5%	5%	55%	25%	1.05	1.00	1.20
28	LP Pwrdy 40 + HPs-30 +DEB	0%	100%	0%	0%	15%	8%	7%	40%	30%	1.05	1.00	1.20
29	LP Gas Boiler	0%	100%	0%	100%	0%	0%	0%	0%	0%	1.05	1.00	1.20
30	LP DE Boiler	0%	100%	0%	0.00%	0%	0%	0%	0%	100 %	1.05	1.00	1.20
31	LP GSHP DE Boiler	0%	100%	60%	0.00%	0%	0%	0%	0%	40%	1.05	1.00	1.20
32	LP ASHP Gas Boiler	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
33	LP ASHP DE Boiler	0%	100%	60%	0.00%	0%	0%	0%	0%	40%	1.05	1.00	1.20
34	AF GSHP DE Boiler	0%	100%	60%	0.00%	0%	0%	0%	0%	40%	1.05	1.00	1.20
Notes: LP or AF = London Plan or Advanced fabric; DE(B)boiler = direct electric boiler; GSHP, ASHP, HRHP = ground source, air source and heat recovery heat pumps (HPs); SHW = solar hot water heating; Pwrdy = heat from Powerday energy from waste plant. See Table G.2.5 and Table G.2.6 for fabric specifications and full scenario descriptions.													

Table G.3.1. Heat Source Mixes for Technology Scenarios (Post-processing Inputs)

G.3.2 Carbon Emission Outcomes for Technology Scenarios

G.3.2.1 Average Dwelling Emission Rates

To enable comparison of carbon emission results, the results for different dwelling sizes were combined into a single weighted average figure based on the proportion of homes of each size (see Table G.2.4). Average dwelling emission rates in $kgCO_2/m^2/year$ are set out in Table G.3.2.

G.3.2.2 Reduction in Average Dwelling Emission Rates vs the Counterfactual

Reductions in average dwelling emission rates were calculated relative to the London Plan counterfactual (technology scenario 1), and are set out in Table G.3.3.

G.3.2.3 Interpreting the Results Tables

Cell colouring in Table G.3.2 and Table G.3.3 represents the carbon emission performance relative to the counterfactual, technology scenario 1 (described earlier in Box G.1) in 2016 – unshaded neutral (white). Lower (better) emission rates are shaded green. Higher (worse) emission rates are shaded red. The darker the green or red shading, the lower or higher respectively are the emissions relative to the counterfactual.
The horizontal lines in both tables divide the technology scenarios into three groups:

1. Top group – heat pumps as lead heat generator (except 17 and 18, where they serve hot water only);
2. Middle group – direct electric storage heaters or boilers as lead heat generator; and
3. Bottom group – heat networks with defined mix of heat sources (except 29 gas boilers, included for comparison).

The ‘Gas CHP’ decarbonisation scenario uses a higher grid emission factor for grid-displaced electricity (increasing the carbon ‘credit’ for the electricity generated by the CHP). As such, only technology scenarios that generate (and displace) grid electricity perform differently under this decarbonisation scenario.

[$kgCO_2/m^2/year$, weighted average across units by no. of beds]

	Grid Decarbonisation Scenario >	Slower						Faster						Gas CHP					
TS no.	Technology Scenario	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50
16	AF GSHP ASHP SHW	11.2	7.5	5.0	3.3	1.9	0.9	11.2	6.5	4.3	2.9	1.9	0.9	11.2	6.5	4.3	2.9	1.9	0.9
15	AF GSHP ASHP	12.9	8.7	5.8	3.8	2.2	1.1	12.9	7.5	5.0	3.4	2.2	1.1	12.9	7.5	5.0	3.4	2.2	1.1
8	LP GSHP ASHP SHW	14.5	9.8	6.5	4.3	2.5	1.2	14.5	8.4	5.6	3.8	2.5	1.2	14.5	8.4	5.6	3.8	2.5	1.2
17	AF HRHP	15.8	10.7	7.1	4.7	2.7	1.3	15.8	9.2	6.1	4.1	2.7	1.3	15.8	9.2	6.1	4.1	2.7	1.3
7	LP GSHP ASHP	16.4	11.1	7.4	4.8	2.8	1.3	16.4	9.5	6.3	4.3	2.8	1.3	16.4	9.5	6.3	4.3	2.8	1.3
18	AF HRHP SHW	15.4	10.4	6.9	4.5	2.6	1.3	15.4	8.9	6.0	4.0	2.6	1.3	15.4	8.9	6.0	4.0	2.6	1.3
34	AF GSHP DE Boiler	18.8	12.7	8.5	5.6	3.2	1.6	18.8	11.0	7.3	4.9	3.2	1.6	18.8	11.0	7.3	4.9	3.2	1.6
31	LP GSHP DE Boiler	25.8	17.4	11.7	7.6	4.5	2.1	25.8	15.0	10.0	6.8	4.5	2.1	25.8	15.0	10.0	6.8	4.5	2.1
33	LP ASHP DE Boiler	26.3	17.8	11.9	7.8	4.5	2.2	26.3	15.3	10.2	6.9	4.5	2.2	26.3	15.3	10.2	6.9	4.5	2.2
14	AF GSHP Gas Boiler SHW	11.9	8.9	6.9	5.5	4.4	3.6	11.9	8.1	6.3	5.2	4.4	3.6	11.9	8.1	6.3	5.2	4.4	3.6
6	LP GSHP Gas Boiler SHW	15.8	12.3	10.0	8.3	7.1	6.1	15.8	11.3	9.3	8.0	7.1	6.1	15.8	11.3	9.3	8.0	7.1	6.1
13	AF GSHP Gas Boiler	14.0	10.6	8.4	6.9	5.7	4.8	14.0	9.7	7.8	6.6	5.7	4.8	14.0	9.7	7.8	6.6	5.7	4.8
5	LP GSHP Gas Boiler	18.0	14.1	11.6	9.8	8.4	7.4	18.0	13.1	10.8	9.4	8.4	7.4	18.0	13.1	10.8	9.4	8.4	7.4
32	LP ASHP Gas Boiler	18.5	14.4	11.8	9.9	8.5	7.4	18.5	13.3	11.0	9.5	8.5	7.4	18.5	13.3	11.0	9.5	8.5	7.4
12	AF DE Storage Heater SHW	20.7	14.0	9.3	6.1	3.6	1.7	20.7	12.0	8.0	5.4	3.6	1.7	20.7	12.0	8.0	5.4	3.6	1.7
4	LP DE Storage Heater SHW	30.9	20.9	14.0	9.1	5.3	2.5	30.9	18.0	12.0	8.1	5.3	2.5	30.9	18.0	12.0	8.1	5.3	2.5
11	AF DE Storage Heater	26.9	18.2	12.1	7.9	4.6	2.2	26.9	15.7	10.4	7.1	4.6	2.2	26.9	15.7	10.4	7.1	4.6	2.2
3	LP DE Storage Heater	37.3	25.2	16.8	11.0	6.4	3.1	37.3	21.7	14.4	9.8	6.4	3.1	37.3	21.7	14.4	9.8	6.4	3.1
30	LP DE Boiler	40.5	27.3	18.3	11.9	7.0	3.3	40.5	23.6	15.7	10.6	7.0	3.3	40.5	23.6	15.7	10.6	7.0	3.3
28	LP Pwrdy 40 + HPs-30 +DEB	20.1	14.7	10.5	7.6	5.3	3.6	20.1	13.0	9.3	7.0	5.3	3.6	20.1	13.0	9.3	7.0	5.3	3.6
27	LP Pwrdy 55 + HPs-20 +DEB	17.5	13.5	10.0	7.5	5.6	4.2	17.5	12.0	9.0	7.0	5.6	4.2	17.5	12.0	9.0	7.0	5.6	4.2
26	LP Pwrdy 70 + HPs-10 +DEB	15.0	12.2	9.4	7.4	5.8	4.7	15.0	11.0	8.6	7.0	5.8	4.7	15.0	11.0	8.6	7.0	5.8	4.7
23	LP Pwrdy-70 + HPs-10 + CHP-15	9.0	10.1	10.2	10.2	10.2	10.2	9.0	10.1	10.2	10.2	10.2	10.2	9.0	9.4	8.7	8.2	7.9	7.8
24	LP Pwrdy-55 + HPs-20 + CHP-15	10.5	11.0	10.7	10.6	10.4	10.4	10.5	10.9	10.7	10.5	10.4	10.4	10.5	10.2	9.2	8.5	8.1	7.9
25	LP Pwrdy 40 + HPs-30 + CHP-15	12.1	11.8	11.3	10.9	10.7	10.5	12.1	11.6	11.2	10.9	10.7	10.5	12.1	10.9	9.7	8.9	8.4	8.0
20	LP Pwrdy-70 + CHP-15	9.5	10.9	11.2	11.5	11.6	11.7	9.5	11.1	11.3	11.5	11.6	11.7	9.5	10.4	9.8	9.5	9.3	9.3
21	LP Pwrdy-55 + CHP-35	8.6	12.0	14.0	15.4	16.5	17.3	8.6	12.8	14.5	15.7	16.5	17.3	8.6	11.2	11.1	11.0	11.0	11.5
22	LP Pwrdy-40 + CHP-35	10.7	13.6	15.6	17.0	18.1	18.9	10.7	14.5	16.2	17.3	18.1	18.9	10.7	12.8	12.7	12.6	12.7	13.1

[kgCO₂/m²/year, weighted average across units by no. of beds]

TS no.	Grid Decarbonisation Scenario > / Technology Scenario	Slower						Faster						Gas CHP					
		2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50
29	LP Gas Boiler	21.0	19.0	18.0	17.4	16.9	16.5	21.0	18.6	17.8	17.2	16.9	16.5	21.0	18.6	17.8	17.2	16.9	16.5
10	AF CHP-60 Low Temp	11.2	12.6	14.1	15.1	15.9	16.4	11.2	13.2	14.5	15.3	15.9	16.4	11.2	11.7	11.3	11.1	11.0	11.3
9	AF CHP-60 High Temp	11.7	13.4	15.0	16.2	17.1	17.8	11.7	14.1	15.5	16.4	17.1	17.8	11.7	12.5	12.1	11.9	11.8	12.2
2	LP CHP-60 Low Temp	13.6	17.3	20.6	22.9	24.7	26.0	13.6	18.7	21.5	23.3	24.7	26.0	13.6	16.3	16.5	16.6	16.8	17.7
1	LP CHP-60 High Temp	14.4	18.5	22.1	24.7	26.7	28.1	14.4	20.0	23.2	25.2	26.7	28.1	14.4	17.5	17.7	17.9	18.2	19.1
19	LP 5xCluster CHP-70, Low Temp	11.0	17.0	21.9	25.4	28.1	30.0	11.0	19.0	23.3	26.1	28.1	30.0	11.0	15.7	16.4	16.7	17.2	18.5

Notes: LP or AF = London Plan or Advanced fabric; DE(B)boiler = direct electric boiler; GSHP, ASHP, HRHP = ground source, air source and heat recovery heat pumps (HPs); SHW = solar hot water heating; Pwrdy = heat from Powerday energy from waste plant. See Table G.2.5 and Table G.2.6 for fabric specifications and full scenario descriptions.

Table G.3.2. Average Dwelling Emission Rates for Technical Scenarios, per Development Period & for Each Grid Decarbonisation Scenario

[% change vs. London Plan counterfactual]

TS no.	Grid Decarbonisation Scenario > / Technology Scenario	Slower						Faster						Gas CHP					
		2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50
16	AF GSHP ASHP SHW	-22%	-48%	-65%	-77%	-87%	-94%	-22%	-55%	-70%	-80%	-87%	-94%	-22%	-55%	-70%	-80%	-87%	-94%
15	AF GSHP ASHP	-10%	-39%	-59%	-73%	-84%	-93%	-10%	-48%	-65%	-76%	-84%	-93%	-10%	-48%	-65%	-76%	-84%	-93%
8	LP GSHP ASHP SHW	1%	-32%	-54%	-70%	-83%	-92%	1%	-41%	-61%	-74%	-83%	-92%	1%	-41%	-61%	-74%	-83%	-92%
17	AF HRHP	10%	-26%	-50%	-68%	-81%	-91%	10%	-36%	-57%	-71%	-81%	-91%	10%	-36%	-57%	-71%	-81%	-91%
7	LP GSHP ASHP	14%	-23%	-48%	-66%	-80%	-91%	14%	-34%	-56%	-70%	-80%	-91%	14%	-34%	-56%	-70%	-80%	-91%
18	AF HRHP SHW	7%	-28%	-52%	-68%	-82%	-91%	7%	-38%	-59%	-72%	-82%	-91%	7%	-38%	-59%	-72%	-82%	-91%
34	AF GSHP DE Boiler	31%	-11%	-41%	-61%	-77%	-89%	31%	-24%	-49%	-66%	-77%	-89%	31%	-24%	-49%	-66%	-77%	-89%
31	LP GSHP DE Boiler	80%	21%	-19%	-47%	-69%	-85%	80%	5%	-30%	-53%	-69%	-85%	80%	5%	-30%	-53%	-69%	-85%
33	LP ASHP DE Boiler	83%	24%	-17%	-46%	-68%	-85%	83%	7%	-29%	-52%	-68%	-85%	83%	7%	-29%	-52%	-68%	-85%
14	AF GSHP Gas Boiler SHW	-17%	-38%	-52%	-62%	-69%	-75%	-17%	-44%	-56%	-64%	-69%	-75%	-17%	-44%	-56%	-64%	-69%	-75%
6	LP GSHP Gas Boiler SHW	10%	-15%	-31%	-42%	-51%	-57%	10%	-21%	-35%	-44%	-51%	-57%	10%	-21%	-35%	-44%	-51%	-57%
13	AF GSHP Gas Boiler	-3%	-26%	-41%	-52%	-60%	-66%	-3%	-32%	-46%	-54%	-60%	-66%	-3%	-32%	-46%	-54%	-60%	-66%
5	LP GSHP Gas Boiler	25%	-2%	-20%	-32%	-42%	-49%	25%	-9%	-25%	-34%	-42%	-49%	25%	-9%	-25%	-34%	-42%	-49%

[% change vs. London Plan counterfactual]

	Grid Decarbonisation Scenario >	Slower						Faster						Gas CHP					
TS no.	**Technology Scenario**	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50
32	LP ASHP Gas Boiler	29%	0%	-18%	-31%	-41%	-48%	29%	-7%	-23%	-34%	-41%	-48%	29%	-7%	-23%	-34%	-41%	-48%
12	AF DE Storage Heater SHW	44%	-3%	-35%	-58%	-75%	-88%	44%	-16%	-44%	-62%	-75%	-88%	44%	-16%	-44%	-62%	-75%	-88%
4	LP DE Storage Heater SHW	115%	45%	-3%	-37%	-63%	-82%	115%	25%	-17%	-44%	-63%	-82%	115%	25%	-17%	-44%	-63%	-82%
11	AF DE Storage Heater	87%	26%	-16%	-45%	-68%	-85%	87%	9%	-28%	-51%	-68%	-85%	87%	9%	-28%	-51%	-68%	-85%
3	LP DE Storage Heater	159%	75%	17%	-24%	-55%	-79%	159%	51%	0%	-32%	-55%	-79%	159%	51%	0%	-32%	-55%	-79%
30	LP DE Boiler	182%	90%	27%	-17%	-51%	-77%	182%	64%	9%	-26%	-51%	-77%	182%	64%	9%	-26%	-51%	-77%
28	LP Pwrdy 40 + HPs-30 +DEB	39%	2%	-27%	-47%	-63%	-75%	39%	-10%	-35%	-51%	-63%	-75%	39%	-10%	-35%	-51%	-63%	-75%
27	LP Pwrdy 55 + HPs-20 +DEB	22%	-6%	-31%	-48%	-61%	-71%	22%	-16%	-38%	-51%	-61%	-71%	22%	-16%	-38%	-51%	-61%	-71%
26	LP Pwrdy 70 + HPs-10 +DEB	4%	-15%	-35%	-49%	-59%	-67%	4%	-23%	-40%	-51%	-59%	-67%	4%	-23%	-40%	-51%	-59%	-67%
23	LP Pwrdy-70 + HPs-10 + CHP-15	-38%	-30%	-29%	-29%	-29%	-29%	-38%	-29%	-29%	-29%	-29%	-29%	-38%	-34%	-40%	-43%	-45%	-46%
24	LP Pwrdy-55 + HPs-20 + CHP-15	-27%	-24%	-25%	-26%	-27%	-28%	-27%	-24%	-26%	-27%	-27%	-28%	-27%	-29%	-36%	-41%	-44%	-45%
25	LP Pwrdy 40 + HPs-30 + CHP-15	-16%	-18%	-21%	-24%	-26%	-27%	-16%	-19%	-22%	-24%	-26%	-27%	-16%	-24%	-33%	-38%	-42%	-44%
20	LP Pwrdy-70 + CHP-15	-34%	-24%	-22%	-20%	-19%	-18%	-34%	-23%	-21%	-20%	-19%	-18%	-34%	-28%	-32%	-34%	-35%	-35%
21	LP Pwrdy-55 + CHP-35	-40%	-17%	-3%	7%	14%	20%	-40%	-11%	1%	9%	14%	20%	-40%	-22%	-23%	-24%	-23%	-20%
22	LP Pwrdy-40 + CHP-35	-26%	-5%	9%	18%	26%	31%	-26%	1%	13%	20%	26%	31%	-26%	-11%	-12%	-12%	-12%	-9%
29	LP Gas Boiler	46%	32%	25%	21%	17%	15%	46%	29%	24%	20%	17%	15%	46%	29%	24%	20%	17%	15%
10	AF CHP-60 Low Temp	-22%	-12%	-2%	5%	10%	14%	-22%	-8%	1%	6%	10%	14%	-22%	-18%	-21%	-23%	-24%	-22%
9	AF CHP-60 High Temp	-19%	-7%	5%	13%	19%	24%	-19%	-2%	8%	14%	19%	24%	-19%	-13%	-16%	-17%	-18%	-15%
2	LP CHP-60 Low Temp	-6%	20%	43%	59%	72%	81%	-6%	30%	50%	62%	72%	81%	-6%	13%	15%	16%	17%	23%
1	LP CHP-60 High Temp	0%	29%	54%	72%	85%	96%	0%	39%	61%	75%	85%	96%	0%	21%	23%	25%	27%	33%
19	LP 5xCluster CHP-70, Low Temp	-23%	18%	52%	76%	95%	109%	-23%	32%	62%	81%	95%	109%	-23%	9%	14%	16%	20%	29%

Notes: LP or AF = London Plan or Advanced fabric; DE(B)boiler = direct electric boiler; GSHP, ASHP, HRHP = ground source, air source and heat recovery heat pumps (HPs); SHW = solar hot water heating; Pwrdy = heat from Powerday ‘s proposed energy from waste plant. See Table G.2.5 and Table G.2.6 for fabric specifications and full scenario descriptions.

Table G.3.3. Reduction in Average Dwelling Emission Rates for Technical Scenarios, per Development Period & for Each Grid Decarbonisation Scenario

G.3.3 Commentary on Carbon Emission Outcomes

The carbon emission outcomes for the technology scenarios studied confirm many of the prior expectations of the study team based, on a general understanding of the current relative performance of technologies and the trends in emission factors (particularly for grid electricity):

1. Gas CHP (as main heat source) falls precipitously from being among the best carbon saving options deliverable now to definitively the worst of the options studied by 2021 – 25 under all the emissions scenarios considered. While the use of bespoke gas CHP marginal emission factors reduces the calculated emissions (‘Gas CHP’ grid decarbonisation scenario), this does not alter the relative ranking of the technology choices.

2. Heat pumps supplant gas CHP as the main heat source providing the lowest carbon emissions from the start of the 2020s.

3. Heat pump and direct electric options have the best carbon outcomes in the long term but in the short term either have the worst carbon outcomes (direct electric), which will not meet London Plan carbon targets (and may not enable homes to meet Building Regulations Part L) or are relatively costly to install (ground source heat pumps), as will be discussed later.

The results also help to draw out the following insights:

1. Heat from a proposed Energy from Waste facility appears critical to any heat network in the Old Oak area. It enables the carbon intensity of a heat network to remain somewhat competitive (in terms of emission rates) with unit- and block-scale electric heating options into the 2030s.

2. Scenarios including infrastructure scale heat pump options (open loop ground, canal, and sewer source) are the only ones near the top on carbon outcomes throughout the periods considered. Previous work established the capacity of the heat resource for these options of around 10 MW, i.e. approximately 10% of peak heat load at full build out (~100 MW) and perhaps half of the base load for the first 20 years.

3. Scenarios based on heat networks offer the best carbon outcomes in the short term. Electricity-based heating systems (which in practice would be block and unit scale, with no heat network) have the best long term outcomes. There is little common ground between these options and therefore it is not obvious how an energy strategy would transition smoothly from one solution to the other.

G.4 Costs

This section below provides a comparison of the capital costs and occupant running costs for the alternative energy strategy options being considered for the proposed development in the Old Oak area.

G.4.1 Capital Costs

G.4.1.1 Introduction

The capital costs of delivering energy and CO_2 reduction targets impact scheme viability and are therefore an important consideration for developers. Indicative capital costs have been produced to enable energy technology scenarios to be compared, alongside their estimated CO_2 savings and running costs for occupants. The estimates include costs for individual technology components, associated plant and site infrastructure, as well as building systems and/or services within dwellings where these varied across options.

The comparative costs are presented relative to the counterfactual 'default London Plan-compliant' scenario with gas-CHP as the low carbon heat source for each of the development parcels.

Please refer to section G.2.2.3 for further details on the counterfactual 'scenario and the alternative technology scenarios modelled.

G.4.1.2 Methodology, Data Sources and Limitations

The cost estimates are derived based on a bottom up analysis using a combination of published reference sources and internal AECOM data from previous projects. High level estimates have been developed for system sizes taking into consideration the site context, housing densities and projected heat demand profiles. For certain cost items, such as indicative length of primary pipework for district heating network, estimates are based on AECOM experience from schemes with similar housing densities.

Table G.4.1 below summarises the cost items that were included in the comparative analysis.

Scale	Cost components
Development scale 'market delivery' option	Heat generation plant (gas CHP and ancillaries) Gas boilers to meet peak demand Energy centre, assumed to be located in basement for smaller plots, standalone building for large development parcels (i.e. Old Oak North and Old Oak South), excludes land costs Primary district heating pipework Block level heating sub-stations Secondary distribution pipework Heat interface units (HIUs) within dwellings Heat emitters (radiators) London Plan compliant fabric specification
Cluster level options	Heat generation plant (gas CHP and ancillaries/ heat pump technologies) Connection to Energy from Waste (EfW) plant Gas boilers to meet peak demand Standalone energy centre building District heating transmission network connecting energy centres in each cluster Primary district heating pipework to plot boundary Block level heating sub-stations Secondary distribution pipework HIUs within dwellings Heat emitters (radiators/ low temperature underfloor heating depending on network flow and return temperatures) London Plan compliant fabric specification

Scale	Cost components
Block level options	Heat generation plant (ground source/ air source heat pumps/ direct electric) Block level energy centre Secondary distribution pipework HIUs within dwellings Heat emitters (low temperature underfloor heating) Solar water heating for specific options London Plan compliant/ advanced fabric specification
Unit level options	Heat generation technology (exhaust air heat pumps/ electric storage heaters) Solar water heating for specific options Hot water cylinder in dwellings London Plan compliant/ advanced fabric specification

Table G.4.1. Cost Components for Technology Scenarios

The cost estimates reflect 1st Quarter 2017 prices and do not reflect anticipated changes or inflationary increases in technology and infrastructure costs over time. Costs include prelims, overheads and profits. No allowance has been made for professional fees and contingencies. It is worth noting there is a high level of uncertainty associated with capital cost estimates at design development stage. The uncertainty comes from a whole host of variables, such as technical assumptions around system sizes and specifications, lack of reliable cost data for newer technologies that are not mainstream in the UK (such as sewer based heat pumps or advanced fabric specification in high rise construction), site-specific variables and risks (e.g. cost implications of routing district heating pipework under railway lines or other obstructions), as well as the impact of delivery and procurement routes (for instance the ability to combine district heating infrastructure with other ground infrastructure).

Specifically on the additional cost of delivering an advanced energy efficiency fabric specification relative to a London Plan compliant specification, this is based on estimates produced by Zero Carbon Hub (Feb 2014) for a low rise block of apartments, which is adjusted using AECOM's Building Cost Index to indicatively bring it to current prices. There is limited published data currently on cost implications of delivering advanced and/or PassivHaus standard for high rise apartments in the UK. The additional cost can vary depending on the construction system used, glazing ratios, baseline ventilation strategy, and other variables.

The current comparative analysis is based on total capital costs associated with alternative strategy options. The net cost to the developer can also vary depending on the procurement strategy for energy infrastructure, e.g. ESCo equity contributions. These could potentially reduce the upfront cost burden for developers with the area wide options expected to benefit most from this (because of the scale and potential commercial attractiveness to ESCos), and to a lesser extent the development scale options.

G.4.1.3 Comparative Capital Costs of Alternative Energy Strategy Options

The estimated percentage uplift in capital costs for alternative energy technology scenarios relative to the development scale 'market delivery' option are set out in Table G.4.2 below. These indicate that:

- The alternative district heating options at cluster level are broadly comparable in cost to the development scale 'market delivery' option. The additional investment in primary distribution pipework and transmission network for the cluster level options is offset by efficiencies in delivering 5 large energy centres as opposed to a number of smaller energy centres at development scale. These efficiencies are reflected in a reduction in cumulative footprint for the energy centres, reduction in back-up plant capacity, as well as lower unit costs of MW scale gas-CHP plant. Cluster level options also create opportunities to tap into Powerday's proposed 'Energy from Waste' plant, connecting to which is a relatively low capital cost investment in comparison to gas CHP as the baseline technology.

- Ground source heat pumps with direct electric top up at block level are also broadly comparable in costs to the development and cluster level DH options. This technology scenario is however expected to have implications for electrical infrastructure costs at the block level which are not quantified as part of this current comparison and will need further analysis. Heat pump technologies at both block and unit level end up with much higher capital costs in comparison when combined with advanced fabric specification.
- Dwelling based direct electric heating technologies have the lowest costs in comparison, though these start to become comparable to the development scale 'market delivery' option and cluster level options when combined with solar water heating and advanced fabric specification.

TS no.	Technology scenario*	Fabric specification	Scale	Capital cost** uplift (approx.)	Annual running cost uplift (approx.)
12	Direct electric storage heater + solar hot water	Advanced	Unit	-5%	-35%
4	Direct electric storage heater + solar hot water	London Plan	Unit	-45%	-20%
11	Direct electric storage heater	Advanced	Unit	-20%	-40%
3	Direct electric storage heater	London Plan	Unit	-60%	-20%
18	Exhaust ventilation air heat recovery heat pump + solar hot water	Advanced	Unit	55%	60%
17	Exhaust ventilation air heat recovery heat pump	Advanced	Unit	40%	50%
34	Ground source heat pump (60%) + direct electric boiler (40%)	Advanced	Block	45%	-30%
31	Ground source heat pump (60%) + direct electric boiler (40%)	London Plan	Block	5%	-15%
1	**Gas CHP (60%; η elec = 36%) + gas boiler (high temp network)**	**London Plan**	**Development**	**0%**	**0%**
25	Powerday (40%) + heat pump (30%) + gas CHP (15%) + gas boiler (15%)	London Plan	Cluster	5%	-5%
22	Powerday (40%) + gas CHP (35%, η elec = 39%) + gas boiler (25%)	London Plan	Cluster	0%	-5%
19	Gas CHP (70%, η elec = 39%) + gas boiler (30%)	London Plan	Cluster	5%	-5%
28	Powerday (40%) + heat pump (30%) + direct electric boiler (30%)	London Plan	Cluster	0%	-5%
23	Powerday (70%) + heat pump (10%) + gas CHP (15%) + gas boiler (5%)	London Plan	Cluster	0%	-5%

* Please refer to Table G.2.5 and Table G.2.6 for a description of the technology scenarios and their characteristics.
** Cost comparison does not include cost for roof mounted PVs for the development level counterfactual scenario or where this technology may be compatible with any of the others scenarios being analysed.

Table G.4.2. Comparative Costs of Energy Technology Scenarios

When comparing capital costs, it is worth noting that each of the energy strategy options are not directly comparable in terms of the CO_2 impact, and fare better or worse relative to the development scale' market delivery' option at different points in time in the future. Similarly, the impact on heating energy bills for occupants also varies for the alternative options, which is discussed further in Section 0.

G.4.2 Running Costs for Occupants

A key consideration in arriving at an optimum energy strategy is the impact on running costs for occupants. It is important that the strategy does not lead to unacceptably high costs for occupants relative to other widely available alternatives. This is even more critical given the high proportion of affordable housing to be delivered in the Old Oak area and the mayor's aspiration to increase affordable housing provision.

The sub-section below outlines some of the challenges in comparing heating bills for district heating and dwelling based systems. To enable a like for like comparison across technology scenarios, it makes a case for comparing the total cost for the occupant of owning, operating, maintaining and replacing the systems over its life. Sections G.4.2.2 and 0 set out the comparative figures for the alternative energy strategy options along with a brief discussion of how these are expected to change in the future.

G.4.2.1 District Heating versus Dwelling-based Systems

Comparing running costs for district heating (DH) and communal systems with dwelling based systems on a like-for-like basis is not without its challenges. The occupant's perception of the 'cost of heating' is often based on the bill that lands at their door. This typically consists of a variable cost calculated based on a unit cost of heat or fuel, and fixed charges that are independent of consumption. The differences in annual heating bills for occupants connected to a district heating systems versus dwelling based systems stem from how both these cost elements are calculated and, in particular, the inclusions and exclusions.

In general terms it is typical for larger market-led DH schemes to set the total cost of heat (including variable and fixed charges) to the occupant to be no higher (or marginally lower) than the cost of owning, operating, maintaining and replacing a conventional gas boiler heating system. With this parameter essentially fixed it then determines the financial return for the DH scheme and whether it will be economic to invest in and operate.

In determining the cost of heat, the heat network operator will take into account the price the occupant would pay for heat (including both variable charges and utility standing charges) as well as anticipated annual service costs, maintenance costs and replacement costs for the boiler. In reality many occupants do not take out a service contract on their boiler, often choosing to pay to have the boiler repaired or replaced when and if it breaks down. Their annual energy bill when connected to district heating will therefore seem much higher than the energy bill for a conventional gas heating system. In effect though the costs involved in owning, maintaining and replacing the conventional dwelling based system have been deferred to future years and often incurred as a lump sum.

To add to the complexity, data from operational district heating schemes indicates a huge variation in heat costs charged to consumers. The cost variation comes from differences in how the schemes are developed and financed (e.g. where these have benefited from significant capital grants), ownership models (for instance, where schemes have adopted existing assets thereby negating the need to recover upfront investment through heat sales) and other priorities (e.g. local authority led schemes where mitigating fuel poverty is high on the agenda).

An AECOM study for DECC[4] (2015) that looked at heat price data from 7 operational DH schemes indicated a price range of 4.64 – 9.88 p/kWh. Non-bulk schemes supplying heat directly to the end residential consumer typically sit at the upper end of this range. The study estimated that in comparison the total cost of heat for the counterfactual gas boiler system would translate to just over 10p/kWh for a small efficient dwelling with a low annual heat demand (such as a new build flat) with around 4.6p/kWh of that being attributable to the boiler ownership costs (i.e. maintenance and replacement).

A *Which?* Report (March 2015)[5] suggested a broader range of heat costs for district heating customers based on data collected from 40 metered schemes including both private and social housing. To enable a comparison of the cost of heat across these schemes, the unit rates and fixed charges were translated into an aggregate p/kWh figure using annual space heating and hot water demand for a typical new built 2-bed flat. This gave a total cost of heat ranging between ~5.5 -15p/kWh, with the average figure of around 11p/kWh. The estimated counterfactual cost of between 9.55 -11.60p/kWh for the gas boiler system compares well with this average figure.

4 DECC, Assessment of the costs, performance, and characteristics of UK heat networks, 2015
5 Which?, Turning up the heat: Getting a fair deal for district heating users, March 2015

The figures from the DECC and *Which?* reports suggest that heat costs for currently operational district heating schemes are on average broadly comparable to the total cost of owning, operating, maintaining and replacing a conventional gas boiler system for smaller new build dwellings (such as would be the case for proposed development in the Old Oak area). Typically the lower annual heat demand baseline for flats means the fixed costs when connected to a DH scheme are a significant proportion of the total bill, close to around 50%.

For comparison, the heat tariffs for residential consumers on the Queen Elizabeth Olympic Park are set out in the table below alongside the figures from the DECC and *Which?* reports. The Olympic Park offers a useful comparator because of the scale and the London location. Assuming a heat demand of 5000 kWh per annum (the figure used in the DECC report for a small efficient dwelling), the heat costs and billing and metering charges for consumers on the Olympic Park translate to 7.5p/kWh, somewhat higher than the 5.7p/kWh fuel costs and standing charges for the counterfactual system as estimated in the DECC and Which? reports.

	Total cost of heat for DH schemes	Estimated counterfactual costs for small efficient dwelling with gas boiler (p/kWh)
DECC (2015)	4.64 – 9.88 p/kWh Average cost 6.43 p/kWh	10.24 p/kWh, broken down as 5.68 p/ kWh for fuel costs and standing charges [4.2 p/kWh for fuel costs alone] 4.57 p/KWh for boiler maintenance and replacement
Which? (2015)	5.51 – 14.94 p/kWh Average cost 11.04 p/kWh	9.55 – 11.60 p/kWh, broken down as 5.73 p/kWh for fuel costs and standing charges 3.18 - 5.23 p/KWh for boiler maintenance and replacement
Queen Elizabeth Olympic Park	Unit cost of heat 5.49 p/kWh Metering and billing 99.85 £/year Availability charge 22.84 £/year per kW heat capacity Additional variable charge where secondary distribution losses > 15%	Not known

Table G.4.3. Total Cost of Heat for District Heating and Individual

The huge range in cost of heat in the figures above highlights instances where district heating consumers may be paying significantly lower or higher for their heat in comparison. Greater transparency on charging structures and costs, e.g. through voluntary initiatives such as the Heat Trust[6], will ensure that consumers energy bills remain broadly comparable with other widely available technology options.

Experience from the Olympic Park and other operational schemes suggests that consumers may also incur additional charges for distribution losses where these exceed set thresholds, for instance, in case of Olympic Park where the secondary pipework losses exceed 15%. This highlights the need for ensuring that district heating systems are designed, operated and managed efficiently to minimise the impact on consumer energy bills, and emphasises the importance of defining the key technical requirements for design of the secondary network to facilitate this.

Most existing district heating networks in the UK are served by gas boilers and gas CHP engines, and occasionally biomass boilers or waste heat sources. The historic charges reflect the fact that it is possible to create viable networks that can compete on price when operating on these heat sources. Our analysis of carbon emissions shows that as the electricity grid decarbonises it will become favourable to shift from gas CHP based systems to electric heat pumps or direct electric boilers. Given the relatively high cost of electricity compared with gas this is likely to increase the operational costs for the heat network operator, which in turn would either increase the energy cost to the consumer or reduce the internal rate of return to

[6] The Heat Trust is a voluntary standard that sets out the quality and level of service heat suppliers should provide to customers. It also provides an independent process with the Energy Ombudsman for settling complaints between the customers and their heat supplier, which is a free service for customers to access. For more details see www.heattrust.org

the investor/operator. Carrying out a full financial appraisal of the various heat network technology options is beyond the scope of this current work, though any future business case assessment for heat networks utilising alternative low carbon heat sources will need to appraise whether sufficient returns can be obtained to enable economically viable operation while retaining affordable bills for residents.

An assessment for DECC (2016)[7] on the potential for heat pumps to serve district heating networks found that although the technology offers large CO_2 reduction potential alongside a decarbonising electricity grid, the price premium for delivered heat is in the range of 35% -74% at current costs (relative to a counterfactual of DH schemes operating on gas CHP or gas boilers). This is attributed to a combination of factors including high capital costs, high electricity price compared to gas price, and lost revenue from electricity sales compared to schemes with gas-CHP. This price premium for heat is unlikely to drop in future years based on DECC's projected retail fuel costs in the 2020s and 2030s. Refer to section 0 below for further discussion on future cost of heat.

As the UK increasingly shifts to electric heating systems the counterfactual against which district heating costs are benchmarked could also be expected to change.

G.4.2.2 Running Costs for Alternative Energy Strategy Options

Table G.4.1 above sets out the indicative 'running cost' for alternative energy strategy options considered for the Old Oak area. The running cost comparison includes the fuel/ heat bills, any fixed annual charges (such as the utility standing charges or charges for billing and metering) plus the annualised cost to the occupant of owning, maintaining and replacing the system.

The fuel bills for the dwelling based technologies have been estimated based on the current electricity unit prices and standing charges for domestic consumers in London[8]. Economy 7 tariffs have been used for electric storage heaters assuming between 90- 93% off peak usage in line with SAP[9] assumptions. While less efficient, storage heaters were selected in preference to direct electric heaters as they offer greater scope for shifting demand. Replacement costs for storage heaters and/or heat pump options have been converted to equivalent annual costs using a 3.5% discount rate and a 15 year service life. An estimated annual maintenance/ servicing cost is added to this to arrive at the total annual running cost for the technology options. The maintenance costs are assumed to be negligible for storage heaters. For heat pumps, the cost of an annual servicing contract from a prominent heat manufacturer has been used as an estimate.

For the block-based GSHP option, current electricity tariffs for small to medium sized non-domestic consumers in London[10] are used, which were then assumed to be passed down to individual occupants accounting for any secondary distribution losses, along with an annual billing and metering charge. As for dwelling based systems, replacement costs have been converted to equivalent annual costs using a 3.5% discount rate. An estimated annual O&M cost is added to arrive at a total annual running cost figure.

For the district heating options at both development and cluster level, the annual heat bills are estimated based on the current unit price of heat and the billing and metering costs being charged for residential customers connected to the Olympic Park DH scheme. The total running costs are then worked up based on the annualised replacement costs and the cost of an annual servicing contract for a gas boiler as the counterfactual system. Replacement and servicing costs and service life for gas boiler are based on figures from DECC (2015)[11].

Compared to the development scale 'market delivery' option, the running costs are marginally lower for the cluster level, low temperature, district heating options due to reduction in distribution losses.

Block based heat pumps and dwelling level electric storage options fare the best, with the running costs dropping by a quarter relative to the market delivery option when combined with solar water heating and/or advanced fabric specifications. Total running costs are highest for the dwelling based heat pump options primarily due to the high annualised cost of replacement.

[7] DECC, Heat Pumps in District Heating, 2016
[8] BEIS Quarterly Energy Prices, Dec 2016
[9] SAP (Standard Assessment Procedure) is used for building regulation compliance for new dwellings in England.
[10] BEIS Quarterly Energy Prices, Dec 2016
[11] DECC, Assessment of the costs, performance and characteristics of UK heat networks, 2015

G.4.2.3 Future Projections of Cost of Heat

The DECC projections (September 2015)[12] on retail fuel prices indicate that the comparative figures for the variable cost of heat will largely remain unchanged in 2020s and 2030s, though electricity based systems could be marginally worse off. Electricity prices see a marginally higher increase, around 19% by 2030 compared to a 13% increase in gas prices over that timeframe.

[12] DECC, Valuation of energy use and greenhouse gas emissions for appraisal- Data tables, September 2015

G.5 Synthesis of Carbon and Cost Results

Dwelling emission rates for selected technology scenarios are shown alongside corresponding capital cost and annual running cost results in Table G.5.1.

Table G.5.2 presents this information in terms of percentage uplift relative to the counterfactual for the different technology scenarios.

Technology Scenario				Scenario emissions, weighted average per unit [kgCO₂/m²/year]							Cost uplifts [£/unit]	
TS no.	Fabric Specification	Technology Specification	Scale	2016	2017-20	2021-25	2026-30	2031-35	2036-50	Overall average 2017 - 50	Capital cost [/m²]	Annual bill + cost of owning system [/m²/year]
12	Advanced	Direct electric storage heater + solar hot water	Unit-based	20.7	14.0	9.3	6.1	3.6	1.7	5.7	£112	£5.87
4	London Plan	Direct electric storage heater + solar hot water	Unit-based	30.9	20.9	14.0	9.1	5.3	2.5	8.5	£63	£7.61
11	Advanced	Direct electric storage heater	Unit-based	26.9	18.2	12.1	7.9	4.6	2.2	7.4	£95	£5.66
3	London Plan	Direct electric storage heater	Unit-based	37.3	25.2	16.8	11.0	6.4	3.1	10.2	£46	£7.47
18	Advanced	Exhaust ventilation air heat recovery heat pump + solar hot water	Unit-based	15.4	10.4	6.9	4.5	2.6	1.3	4.2	£186	£14.91
17	Advanced	Exhaust ventilation air heat recovery heat pump	Unit-based	15.8	10.7	7.1	4.7	2.7	1.3	4.3	£169	£14.11
34	Advanced	Ground source heat pump (60%) + direct electric boiler (40%)	Block-based	18.8	12.7	8.5	5.6	3.2	1.6	5.2	£171	£6.31
31	London Plan	Ground source heat pump (60%) + direct electric boiler (40%)	Block-based	25.8	17.4	11.7	7.6	4.5	2.1	7.1	£122	£8.00
1	**London Plan**	**Gas CHP (60%; η elec = 36%) + gas boiler (high temp network)**	**Development-based**	**14.4**	**18.5**	**22.1**	**24.7**	**26.7**	**28.1**	**25.0**	**£119**	**£9.34**
25	London Plan	Powerday (40%) + heat pump (30%) + gas CHP (15%) + gas boiler (15%)	Cluster-based	12.1	11.8	11.3	10.9	10.7	10.5	10.9	£122	£9.02
22	London Plan	Powerday (40%) + gas CHP (35%, η elec = 39%) + gas boiler (25%)	Cluster-based	10.7	13.6	15.6	17.0	18.1	18.9	17.2	£116	£9.02
19	London Plan	Gas CHP (70%, η elec = 39%) + gas boiler (30%)	Cluster-based	11.0	17.0	21.9	25.4	28.1	30.0	25.8	£123	£9.02
28	London Plan	Powerday (40%) + heat pump (30%) + direct electric boiler (30%)	Cluster-based	20.1	14.7	10.5	7.6	5.3	3.6	7.2	£120	£9.02
23	London Plan	Powerday (70%) + heat pump (10%) + gas CHP (15%) + gas boiler (5%)	Cluster-based	9.0	10.1	10.2	10.2	10.2	10.2	10.2	£116	£9.02

Table G.5.1. Carbon Emissions and Cost /m² Results Summary for Selected Technology Scenarios

Technology Scenario				Scenario emissions, weighted average per unit [%]							Cost uplifts [%]	
TS no.	Fabric Specification	Technology Specification	Scale	2016	2017-20	2021-25	2026-30	2031-35	2036-50	Overall average 2017 - 50	Capital uplift (approx.)	Annual uplift (approx.)
12	Advanced	Direct electric storage heater + solar hot water	Unit-based	44%	-3%	-35%	-58%	-75%	-88%	-61%	-5%	-35%
4	London Plan	Direct electric storage heater + solar hot water	Unit-based	115%	45%	-3%	-37%	-63%	-82%	-41%	-45%	-20%
11	Advanced	Direct electric storage heater	Unit-based	87%	26%	-16%	-45%	-68%	-85%	-49%	-20%	-40%
3	London Plan	Direct electric storage heater	Unit-based	159%	75%	17%	-24%	-55%	-79%	-29%	-60%	-20%
18	Advanced	Exhaust ventilation air heat recovery heat pump + solar hot water	Unit-based	7%	-28%	-52%	-68%	-82%	-91%	-71%	55%	60%
17	Advanced	Exhaust ventilation air heat recovery heat pump	Unit-based	10%	-26%	-50%	-68%	-81%	-91%	-70%	40%	50%
34	Advanced	Ground source heat pump (60%) + direct electric boiler (40%)	Block-based	31%	-11%	-41%	-61%	-77%	-89%	-64%	45%	-30%
31	London Plan	Ground source heat pump (60%) + direct electric boiler (40%)	Block-based	80%	21%	-19%	-47%	-69%	-85%	-51%	5%	-15%
1	**London Plan**	**Gas CHP (60%; η elec = 36%) + gas boiler (high temp network)**	**Development-based**	**0%**	**29%**	**54%**	**72%**	**85%**	**96%**	**74%**	**0%**	**0%**
25	London Plan	Powerday (40%) + heat pump (30%) + gas CHP (15%) + gas boiler (15%)	Cluster-based	-16%	-18%	-21%	-24%	-26%	-27%	-24%	5%	-5%
22	London Plan	Powerday (40%) + gas CHP (35%, η elec = 39%) + gas boiler (25%)	Cluster-based	-26%	-5%	9%	18%	26%	31%	20%	0%	-5%
19	London Plan	Gas CHP (70%, η elec = 39%) + gas boiler (30%)	Cluster-based	-23%	18%	52%	76%	95%	109%	80%	5%	-5%
28	London Plan	Powerday (40%) + heat pump (30%) + direct electric boiler (30%)	Cluster-based	39%	2%	-27%	-47%	-63%	-75%	-50%	0%	-5%
23	London Plan	Powerday (70%) + heat pump (10%) + gas CHP (15%) + gas boiler (5%)	Cluster-based	-38%	-30%	-29%	-29%	-29%	-29%	-29%	0%	-5%

Table G.5.2. Carbon Reduction and Cost Uplift %Results Summary for Selected Technology Scenarios

G.5.1 Commentary on Carbon Emission and Cost Outcomes

The following summarises the analysis undertaken for carbon and costs performance of the different solution investigated.

1. Heat networks reliant on gas CHP engines as the main heat source are expected to result in the highest calculated carbon emissions. From 2021 onwards, this solution is predicted to result in the highest calculated CO_2 emissions. This makes this solution unattractive for any development post 2021. It also appears unattractive for development pre-2021 as the gas CHP engines will be expected to run for 15-20 years and the calculated cumulative emissions over this period will be higher than most, if not all, other options.

2. A multi-sourced low temperature heat network, where the main heat source is from the proposed Powerday EfW facility, is necessary for any large scale heat network in the Old Oak area. It enables the carbon intensity of a heat network to remain competitive (in terms of emission rates) with unit- and block-scale electric heating options into the 2030s. This would be expected to be integrated with infrastructure scale heat pump options (open loop ground, canal, and sewer source). In later years, direct electric boilers can be included to replace more carbon intensive sources (such as any supporting gas CHP engines or gas boilers). It should however be recognised that not all this benefit may be realised due to the lead in time for the Powerday plant itself, which would not be operational until 2021 at the earliest when the heat loads that can utilise it may be limited due to lack of development coming forward prior to this date. This could potentially be overcome if heat were supplied to wider developments such as North Acton, where loads are expected to build up more quickly, but where at present it may be difficult to deliver an area wide heat network due to the multiple land ownerships and need to agree multiple connection agreements. The benefit of a multi sourced low carbon heat network is dependent on the permitting and planning approval for heat offtake from Powerday's EfW plant. The risks associated with this require further evaluation.

3. Block and unit scale electricity-based heating systems have the best long term CO_2 outcomes. In particular block-level ground source heat pumps (GSHP) with advanced insulation standards are relatively attractive from 2021 onwards. All other block-level GSHP options and unit-level electric storage heating options are relatively attractive from 2021 onwards when the vast majority of the development will be built out. In general, the electricity-based heating options are competitively priced compared to heat network alternatives, both in terms of capital cost and cost to the consumer. However, such options go against London Plan policy which promotes heat networks. These solutions will also require greater electrical infrastructure.

4. If it is necessary to adopt the current London Plan policy, and the need to maintain the ability to deliver a 35% reduction in carbon, the most favourable strategy at least in the early phases would be to deliver area wide heat networks if these could utilise heat from Powerday initially and then increasingly from heat pumps drawing low grade heat from the canal, sewers and the aquifer, and potentially in the later phases from electric boilers.

5. Based on the findings from this study, a multi sourced low carbon heat network could meet OPDC's strategic objectives for the decentralised energy strategy in terms of policy compliance, long term carbon savings and secure energy supply, assuming that Powerday can be utilised.

6. For later development clusters, such as Old Oak South (Crossrail and HS2) that could potentially be delivered much later in the programme (mostly after 2030), it is possible that London Plan policy will change to reflect the observed change in electricity emission reductions. For development clusters delivered after the 2030's flexibility would ideally be retained to deliver block or unit based solutions in place of heat networks, as these would be expected to offer lower carbon emissions at lower cost to consumers and at around the same overall total capital cost.

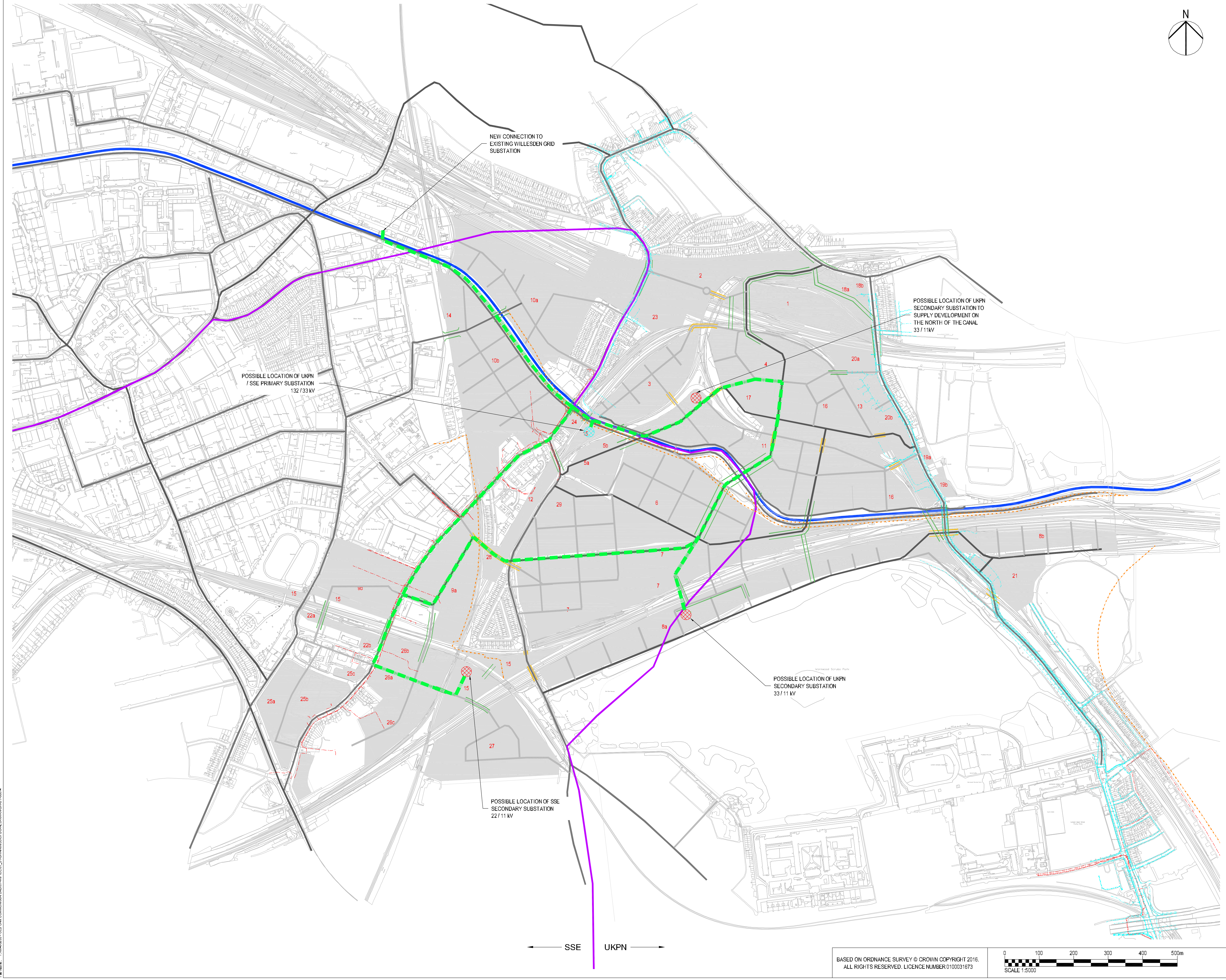
7. It should be recognised that there are some limitations in looking at the overall costs of delivery for the alternative options. One of these is that the costs will fall to different parties depending on the option chosen and the method of procurement. For example while the overall costs of ground source heat pumps (TS 31) are shown to be only slightly higher than the heat network option (TS 25), in reality it may be possible to get a 3rd party ESCO to partially fund the heat network option, so

the capital delivery cost to the Developer may be lower for the district heating option, particularly if it can be delivered at scale.

The analysis presented here indicates that heat networks are likely to be a technically viable solution to ensure low carbon heat supplies are provided to development at OPDC. Initial high level analysis has been carried out to consider some of the opportunities and issues the masterplanning team will need to consider in terms of potential energy centre locations and the likely routes for the primary heat network. This is set out in Appendix C.

Appendix H Electricity Network Improvements

See drawing overleaf.



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KEY

ELECTRICITY INFRASTRUCTURE

- SSE/UKPN BOUNDARY
- NATIONAL GRID ELECTRICITY CABLES
- UKPN ELECTRICITY CABLES (HV)
- PROPOSED HV MAIN (APPROX 50kg/m)
- POSSIBLE PRIMARY SUBSTATIONS
- POSSIBLE SECONDARY SUBSTATIONS

BRIDGES, HIGHWAYS AND CONSTRAINTS

- PROPOSED BRIDGES
- PROPOSED UNDERPASSES
- MAJOR ROADS
- SECONDARY ROADS
- MINOR ROADS
- PADDINGTON BRANCH OF GRAND UNION CANAL

Revision Details	By / Check	Date	Suffix
ASSET REFERENCES REMOVED	MH / JR	30.03.17	P3
MINOR REVISIONS	MH / JR	17.02.16	P2

Purpose of issue

DRAFT

Client

OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title

OLD OAK COMMON

Drawing Title

OLD OAK COMMON ELECTRICITY SUPPLY STRATEGY

Designed	Drawn	Checked	Approved	Date
AW	MH	JR	BM	DEC 2016

AECOM Internal Project No. 60495203

Suitability

Scale @ A1 1:5000

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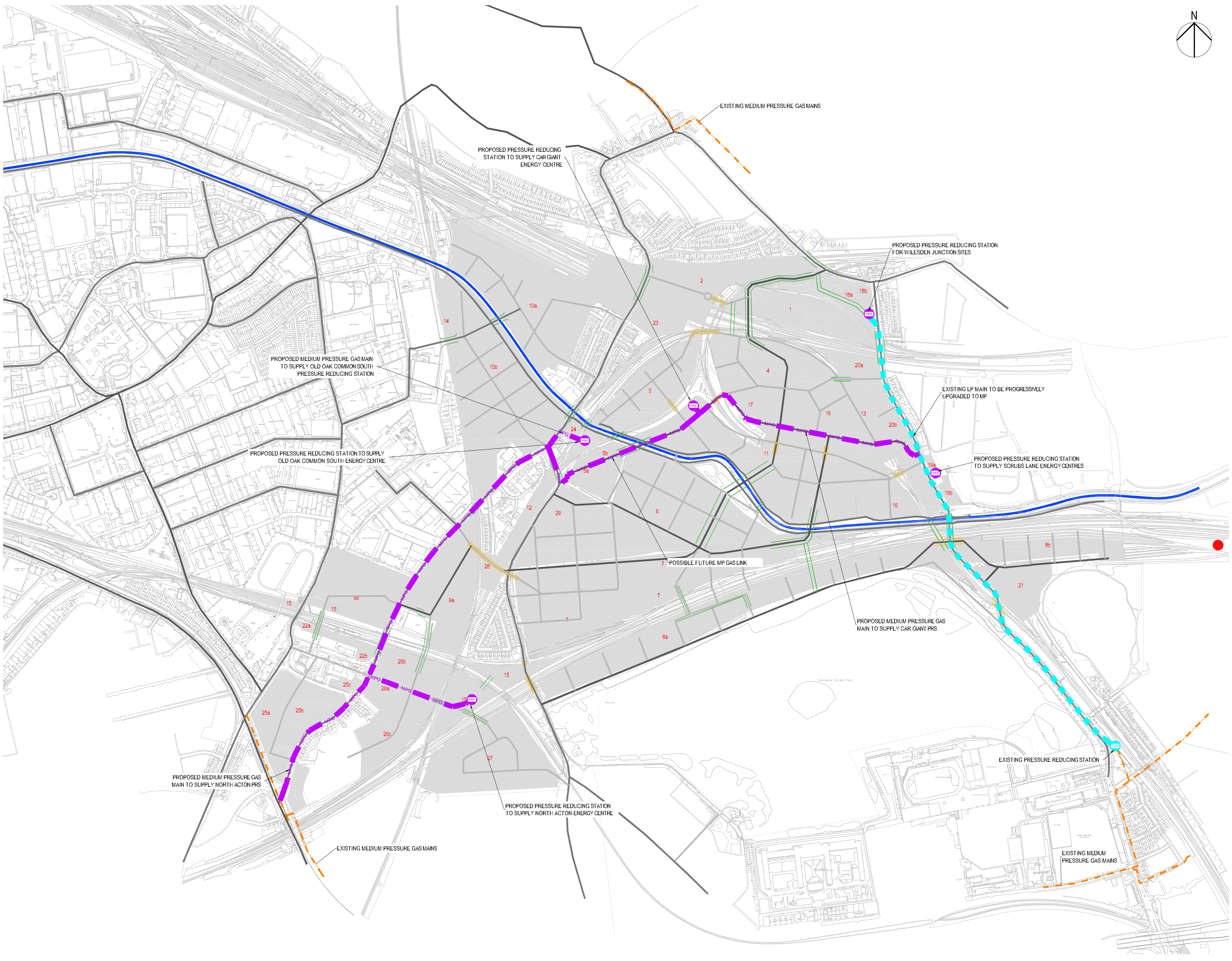
Rev: P3

Appendix I Gas Network Improvements

See drawing overleaf.



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KEY

GAS SUPPLY STRATEGY

- MPG — EXISTING NATIONAL GRID GAS MEDIUM PRESSURE MAIN
- MPG — EXISTING LOW PRESSURE GAS MAIN UPGRADED TO MEDIUM PRESSURE MAIN
- MPG — PROPOSED MEDIUM PRESSURE GAS MAIN
- PRS — PROPOSED PRESSURE REDUCING STATION (PRS)
- PRS — EXISTING PRESSURE REDUCING STATION (PRS)
- EXISTING GAS HOLDER

BRIDGES, HIGHWAYS AND CONSTRAINTS

- PROPOSED BRIDGES
- PROPOSED UNDERPASSES
- MAJOR ROADS
- SECONDARY ROADS
- MINOR ROADS
- PADDINGTON BRANCH OF GRAND UNION CANAL

Revision Details	By / Check	Date	Suffix
ASSET REFERENCES REMOVED	MH / JR	30.03.17	P5
MINOR AMENDMENTS	MH / JR	17.02.17	P4
MINOR AMENDMENTS	MH / JR	04.01.17	P3
MINOR REVISION TO NOTES	MH / JR	23.12.16	P2

Purpose of issue

DRAFT

Client

OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title

OLD OAK COMMON

Drawing Title

OLD OAK COMMON GAS SUPPLY STRATEGY

Designed	Drawn	Checked	Approved	Date
JR	MH	BM	BM	23.12.16

AECOM Internal Project No. 60495203

Suitability

Scale @ A1 1:5000

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Drawing Number: OPDC-AEC-XX-XX-DR-UT-00009

Rev: P5

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Appendix J Thames Water Potable Water Network Impact Assessment

See overleaf.

THAMES WATER UTILITIES LTD

WHOLESALE WATER SPA - WATER MODELLING GROUP

Old Oak Redevelopment – Modelling Impact Assessment - Interim Report

Draft Report – March 2017

Company Confidential

Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 1.0	First Draft for Comment	Rob Dixon	Julie Reynolds	Paolo Teixeira		17/03/2017

This Modelling Study is Valid for a Period of 18 Months from the Date of Authorisation

Contents

FIGURES

Tables

1 Introduction

Developer Services requested a modelling study to investigate the impact of the Old Oak Common redevelopment located in North Acton, North West London, on the distribution network and resource availability of Barrow Hill and Shoot Up Hill Zones.

Old Oak redevelopment site incorporates the Car Giant development site; and together these are part of the wider Old Oak and Park Royal Development Corporation (OPDC) site. The OPDC redevelopment site is bounded by Scrubs Lane to the east, North Circular (A406) to the west and Western Avenue (A40) to the south near North Acton and Park Royal (Figure 1).

The Old Oak development comprises of five phases commencing from 2020 for 20 plus years. The total development will comprise of 27,014 residential units and 720,000 m2 of office floor space.

The demand used in this assessment is a daily demand of 9 Ml/d and peak instantaneous demand of 353.6 l/s for 2040.

No data on the distribution of this demand has been provided at this stage and the point of connection (POC) for the development has been modelled at a single location.

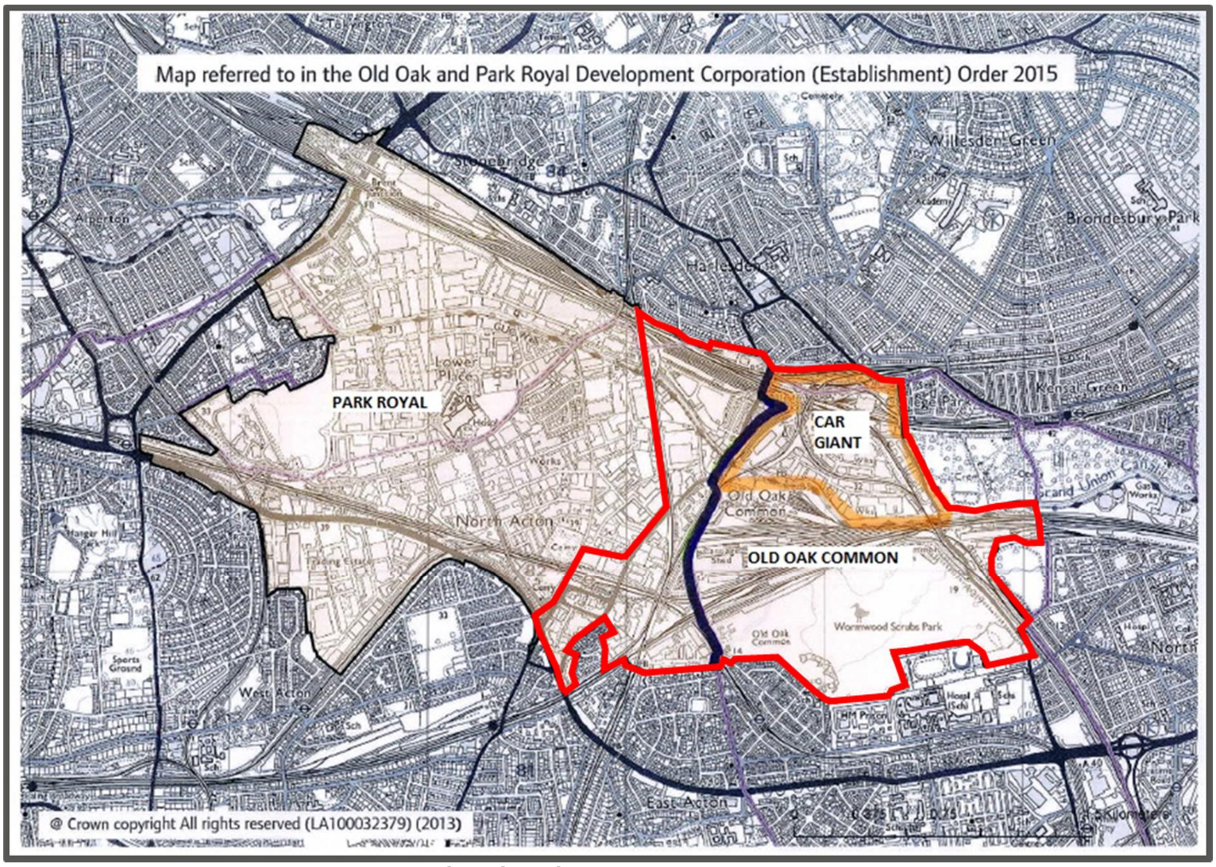


FIGURE 1 – OLD OAK COMMON RE-DEVELOPMENT SITE

1.1 Supply Configuration

The Old Oak Common site geographically extends over three zones: Barrow Hill, Shoot Up Hill and Kempton Flow Monitoring Zones (FMZ). However a review of the network showed that the most suitable trunk mains for supplying the site are in Shoot Up Hill and Barrow Hill zones.

The Barrow Hill and Shoot Up Hill zones are located in North West London and predominantly cover an urban area. The two zones are currently interconnected and are supplied from a variety of sources:

1. Thames Water Ring Main (TWRM) at:
   - Barrow Hill Shaft
   - Holland Park Shaft
   - Park Lane Shaft

2. Hammersmith Pumping Station (PS) located in the south west of the zone, which draws water from Barnes Tank (supplied from the TWRM and Ashford WTW).

3. Infusion from the Kempton 48” trunk main at Cricklewood (ZM13119, ZM13120) which supplies water into the north of Shoot Up Hill zone via 42” twin trunk mains.

4. Willesden Reservoir (Top Water Level (TWL) = 57.52 mAOD) has a bi-directional flow into Barrow Hill and Shoot Up Hill zones, it also provides the suction to Willesden Boosters which supply Bishops Wood Zone.

5. Dollis Hill Reservoir (TWL = 78.73 mAOD) provides water storage for the Shoot Up Hill zone.

6. Barrow Hill Reservoir (TWL = 57.31 mAOD) is located in Barrow Hill Zone

The current average daily demand for ZBARHT and ZSUHIL FMZ’s is 116.58 Ml/d and 100.91 Ml/d respectively.

The area schematic for the Barrow Hill FMZ is shown in Figure 2 below.

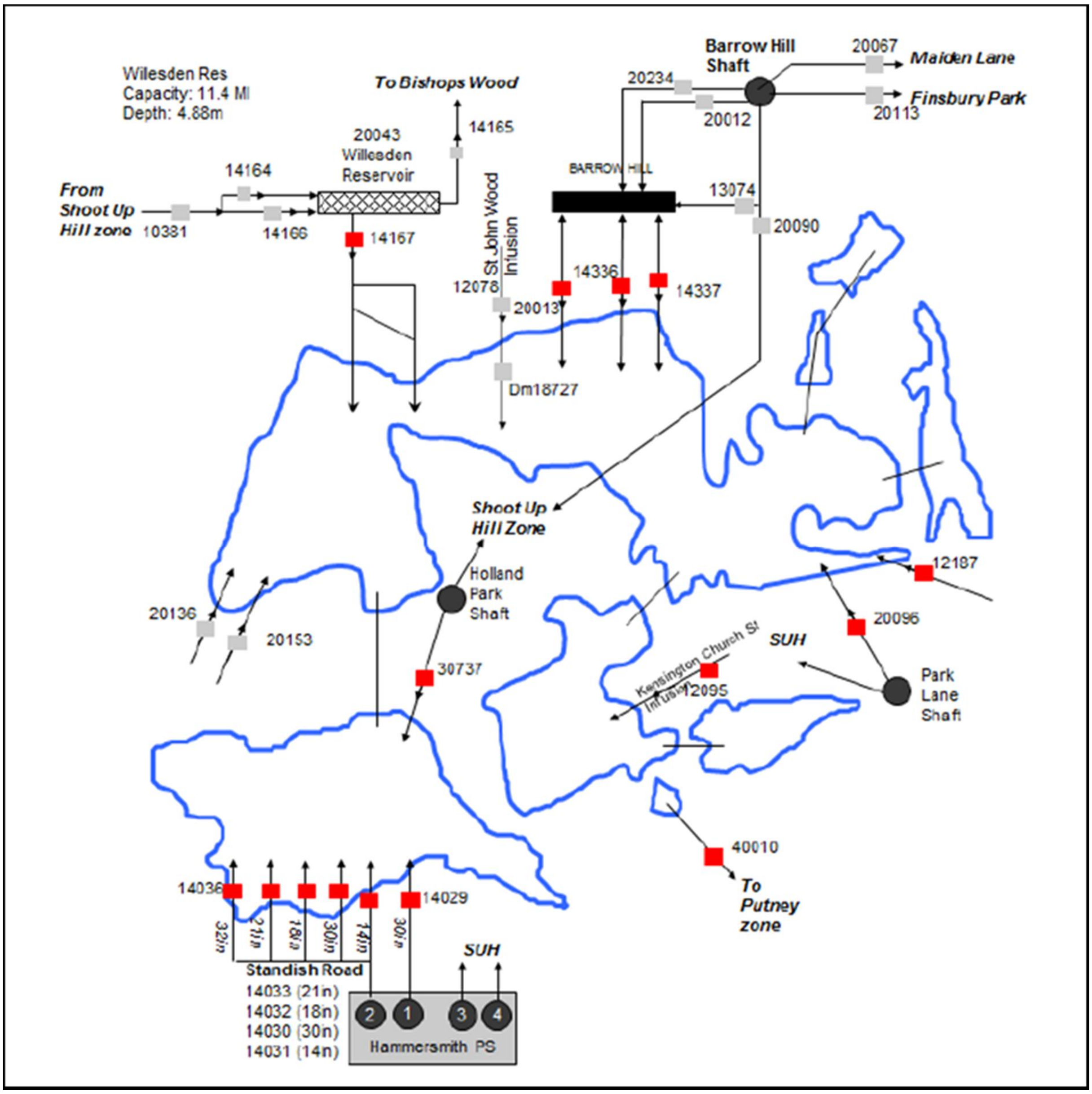


FIGURE 2 – BARROW HILL AREA SCHEMATIC

The area schematic for the Shoot Up Hill FMZ is shown in Figure 3 below.

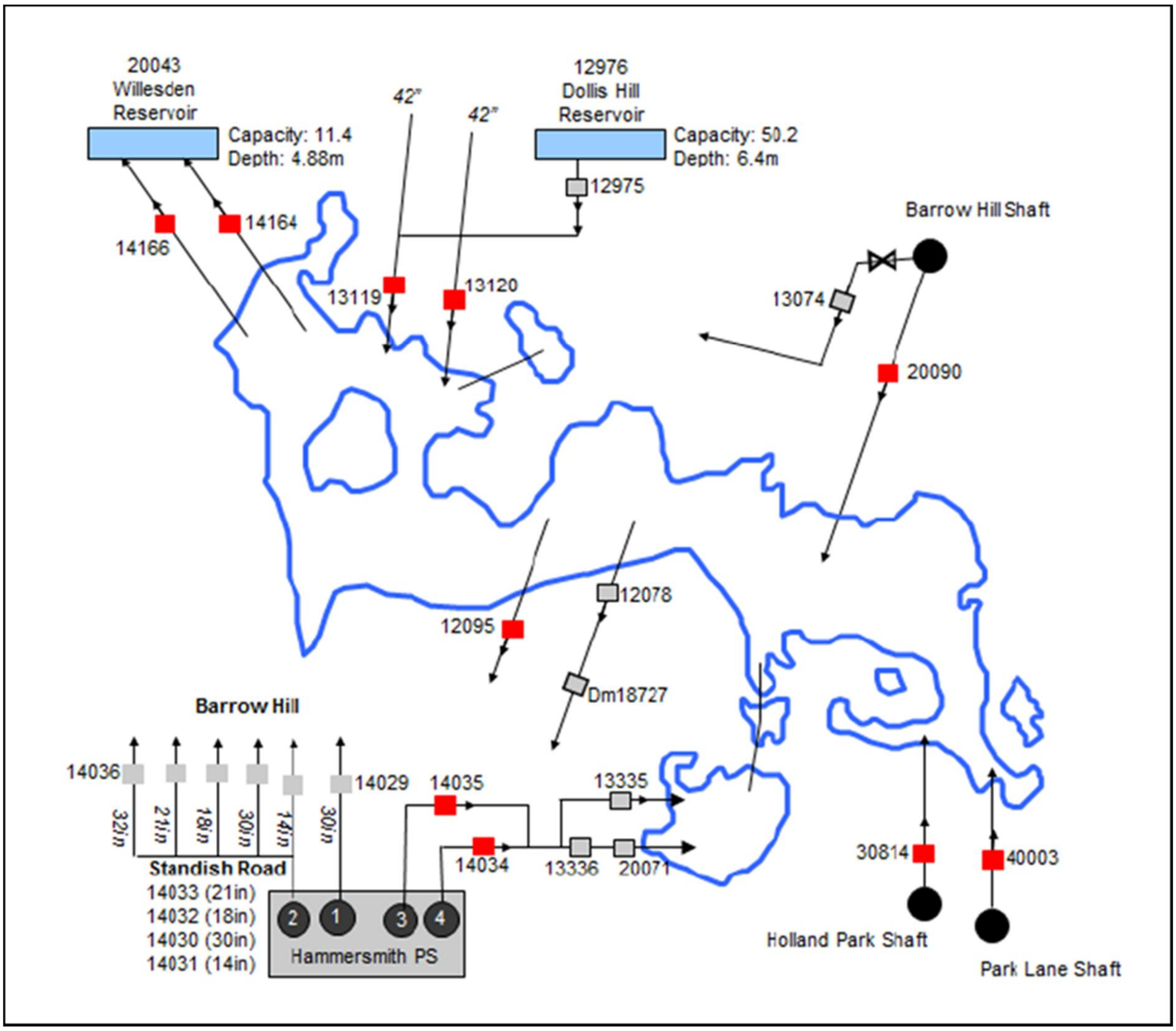


FIGURE 3 – SHOOT UP HILL AREA SCHEMATIC

2 Scope of Work

This study is for the Old Oak Common redevelopment in North West London. The proposed development is constructed over five phases between years 2020 – 2040. The total development will comprise of 27,014 residential units and 720,000 m2 of office floor space.

The aims of this study are:

- To assess the impact of the development on the distribution network for the 2040 demand scenario.
- To review the resource available in North West London to supply the development.
- Provide solution options for new infrastructure, if necessary.

3 Methodology

3.1 Resource Availability

A supply/demand balance has been carried out to determine the availability of water for the final 2039/40 planning period for a Dry Year Critical Period Peak Week with Headroom scenario (DYCP PW + HR).

3.2 Network Impact

The hydraulic analysis of the impact of the proposed development was carried out using the Barrow Hill and Shoot Up Hill FMZs 'all mains' model. The impact of the development on the water distribution network was evaluated in conjunction with Dry Year Critical Period Peak Day with Headroom (DYCP PD + HR) 2039/40 demand scenario, by comparison of network pressures with and without the proposed development incorporated.

4 Development Site

4.1 Site Supply

The location and full phasing of the Old Oak developments are shown in Figure 4. The development site geographically covers Barrow Hill, Shoot Up Hill and Kempton FMZ's. The site is bounded by Scrubs Lane to the east, Willesden Junction Station to the north, North Circular (A406) to the west and the A40 (West Acton) to the south and is sited on the areas of Park Royal to the west and Old Oak Common to the east.

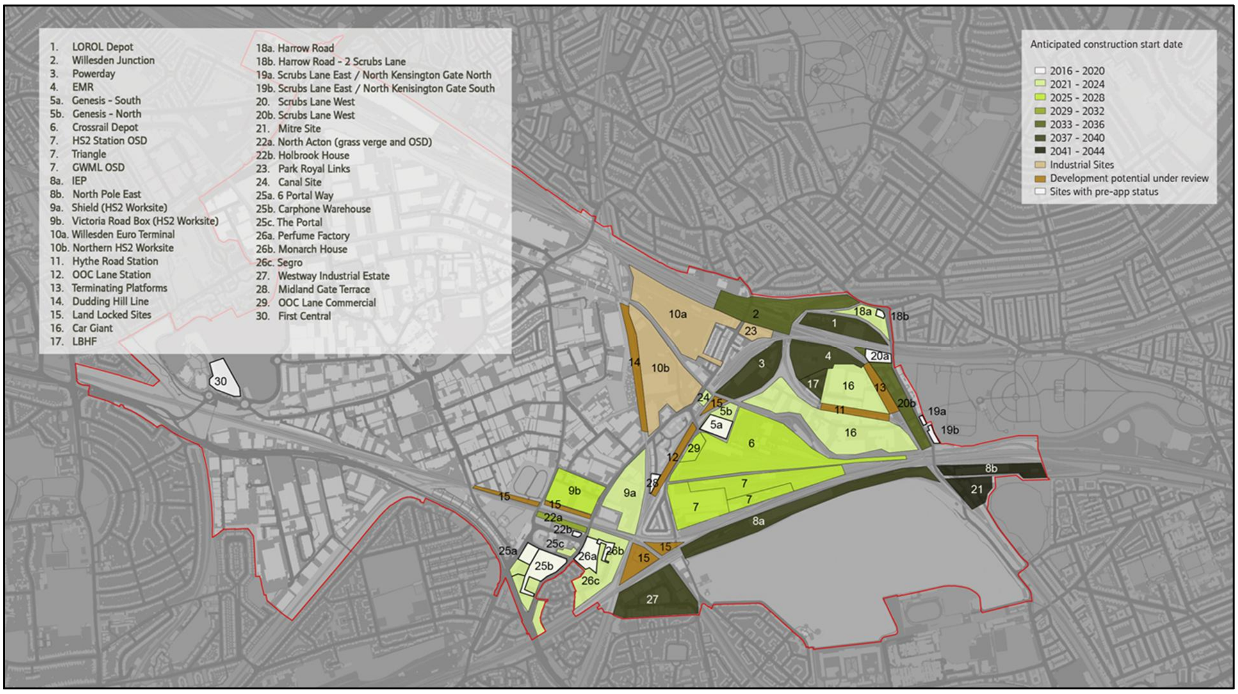


FIGURE 4 – DEVELOPMENT SITE

The proposed POC was selected at a node downstream of District Meter 18798 (DM18798) which is the current connection for Car Giant in Hythe Road see Figure 5.

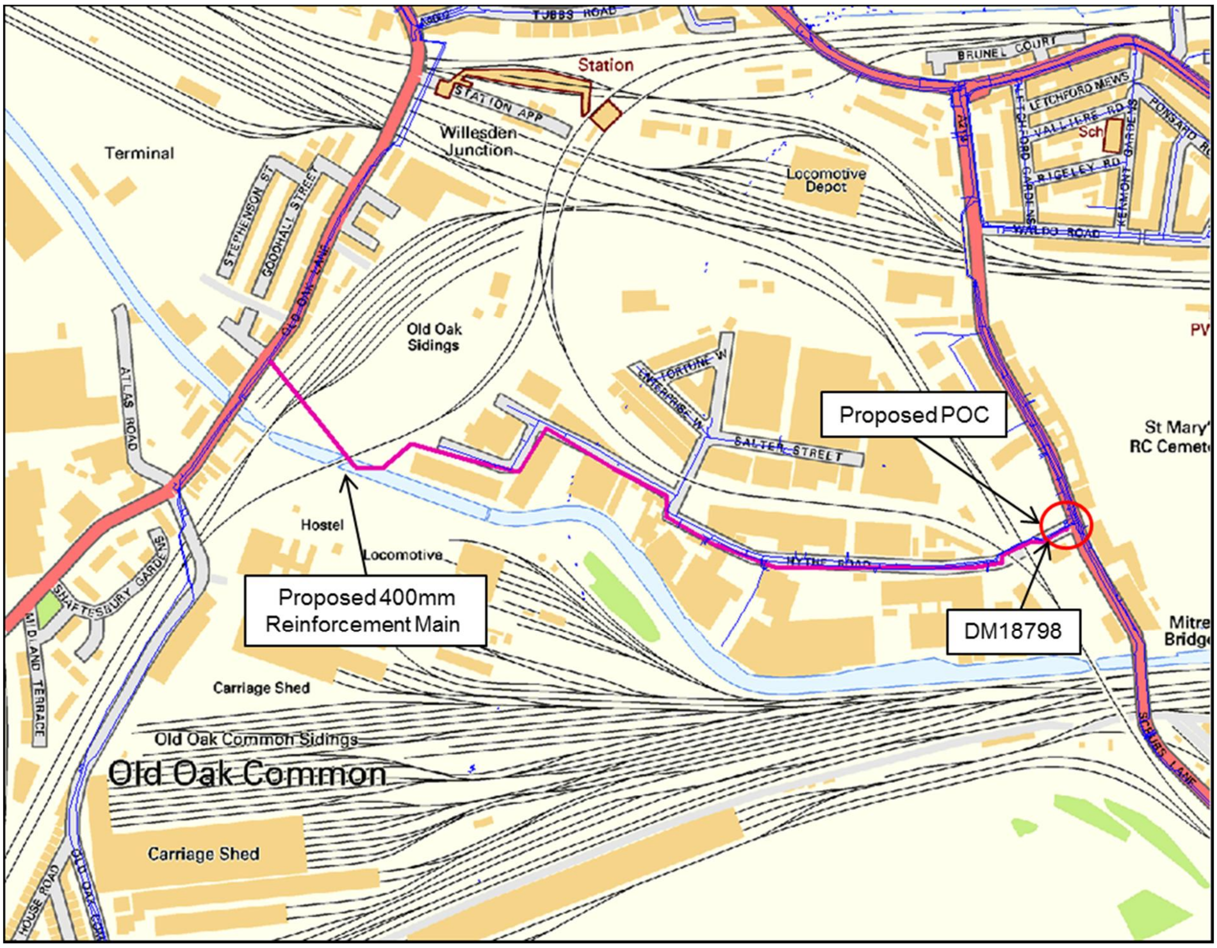


FIGURE 5 – PROPOSED POC LOCATION

The conclusion from the previous Car Giant detailed development study (November 2016), indicated the proposed development would have a significant impact on the pressures in the local area without any enhancements to the network. The Car Giant development is phase 2 of the Old Oak Development (phase 2 = 2025 – 2030)). Option 2B was recommended to maintain the 2025 modelled level of service and resilience. The proposals were:

The proposed POC at the existing supply site, DM18798 originally fed off the 21" Cast Iron (CI) main at the junction of Hythe Road and Scrubs Lane, would be connected into the 16" Barrow Hill main in Scrubs Lane instead.

A rezone of the boundary of Shoot Up Hill onto Barrow Hill between the 21" and 16" CI mains running along Scrubs Lane and a 16" cross connection between these two mains.

A new reinforcement main with a diameter of 315 mm PE100 SDR17 and length of 1.13 km to be connected to the Shoot Up Hill 30" CI main in Old Oak Lane, and to be laid across the Car Giant site to DM18798, see Figure 6.

A new district meter on the new reinforcement main at the POC with the Shoot Up Hill 30" main

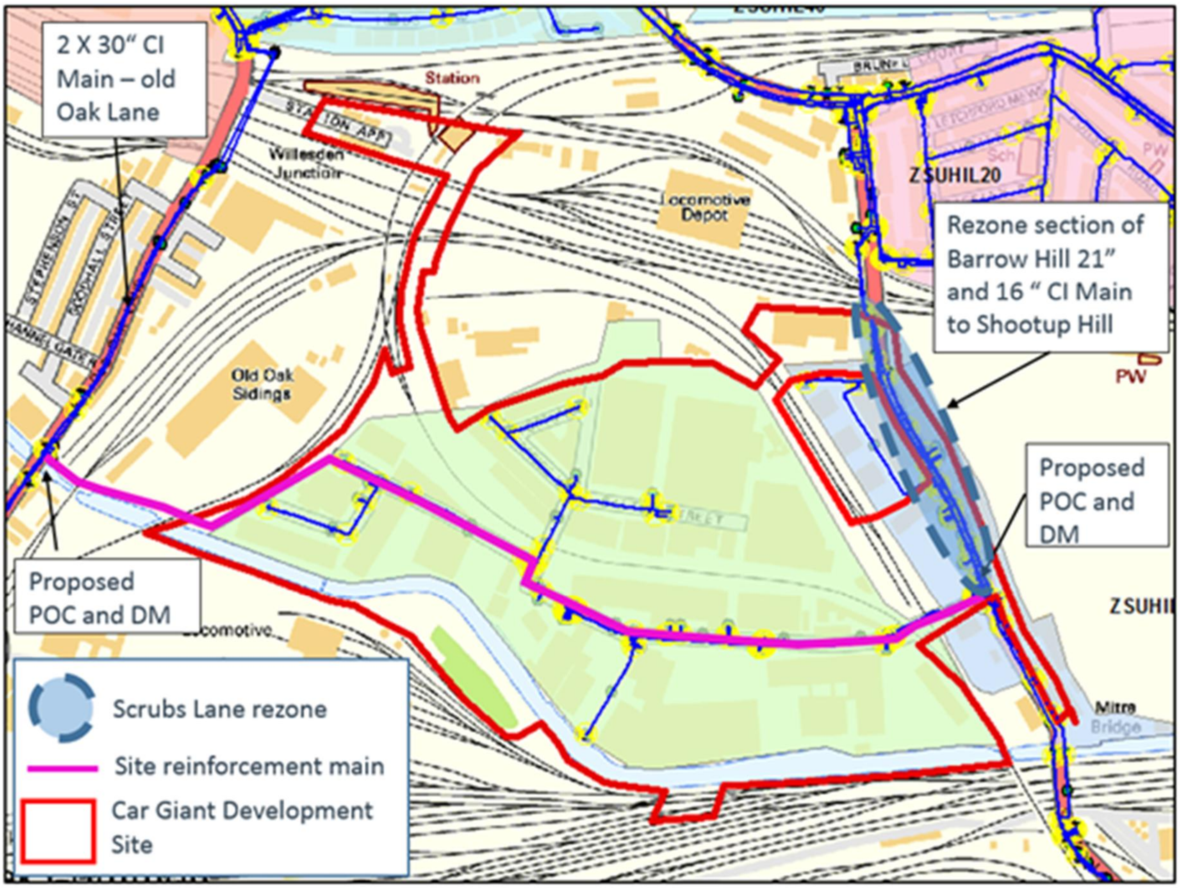


FIGURE 6 – CAR GIANT OPTION 2B

5 Supply and Demand Data

5.1 Development Demand Data

Details on the proposed development have been supplied together with the general layout as shown in Figure 7.

FIGURE 7 – PROPOSED DEVELOPMENT PHASES

The supply requirement has been based on the total of the 5 phases. Table 1 details the timescales, residential units and commercial area of each phase.

Phase	Plots	Year	Residential units	Office/Retail area Sq/m
1	0 - 5 years	2020 - 2025	4,914	51,000
2	5 - 10 years	2025 - 2030	6,449	80,000
3	10 - 15 years	2030 - 2035	5,538	561,000
4	15 - 20 years	2035 - 2040	4,346	14,000
5	20 years ++	2040 -	5,767	14,000
		Total	**27,014**	**720,000**

Table 1 – Phasing Numbers

Table 2 below gives a summary of the demand for the proposed development site.

	2040	
	Daily Demand [Ml/d]	**Peak Morning [l/s]**
Old Oak Development	9	353.62

Table 2 – New Development Demand

5.2 Supply Demand Balance

The supply/demand balance was completed with the latest demand forecasts (v8.3) for the North-West London network. The development daily demand figure of 9 Ml/d was split between Barrow Hill & Shoot Up Hill zones for the 2040 scenario. The supply/demand balance illustrates that there are the resources available from the ring main shafts to meet the additional daily demand. It should be noted that although pumping from the shafts have been increased to the near limits of the pumps. It is the capacity of the network to supply the peak demand, which will be the main constraint.

Appendix B shows the 2039/2040 DYCP PW + HR supply/demand mass balance, with the development demand included.

6 Hydraulic Network Modelling

The hydraulic analysis to assess the impact of the proposed Old Oak development was carried out using the InfoWater model for the area “ZBARHTZSUHIL_CAL_OCT2015_V1”.

Scenario A1 (Base 2040 Peak Day model) this model has been created by factoring the demands using the latest Demand Forecast Data, v8.3. The pump sets have been adjusted to meet the 2040 increase in zonal demand.

Scenario A2 (Impact model) the model was then subsequently created by adding the Old Oak development demand on node 1372540 downstream of DM18798.
The pump sets have been set up to represent the supply/demand balance results and meet the additional 9 Ml/d demand increase for the Old Oak development:

Barrow Hill Zone

- Holland Park pumps set to 40 Ml/d
- Barrow Hill pumps set to 30 Ml/d
- Hammersmith pumps set to 40 Ml/d

Shoot Up Hill Zone

- Holland Park pumps set to 23 Ml/d
- Barrow Hill pumps set to 75 Ml/d
- Hammersmith pumps set to 34 Ml/d

Scenario A3 (Solution Model) the network was updated with the development site’s POC re-sited onto the 30” CI main in Old Oak Lane on Shoot Up Hill Zone to the west of the site rather than from Barrow Hill and with a 400 mm PE100 SDR17 main running through the site to the

16” CI Barrow Hill Main in Scrubs Lane. The 16” CI Barrow Hill zone main in Scrubs Lane needs to be rezoned onto Shoot Up Hill zone (see Figure 6).

Scenario A4 all the other known new developments were added to scenario A3 model.

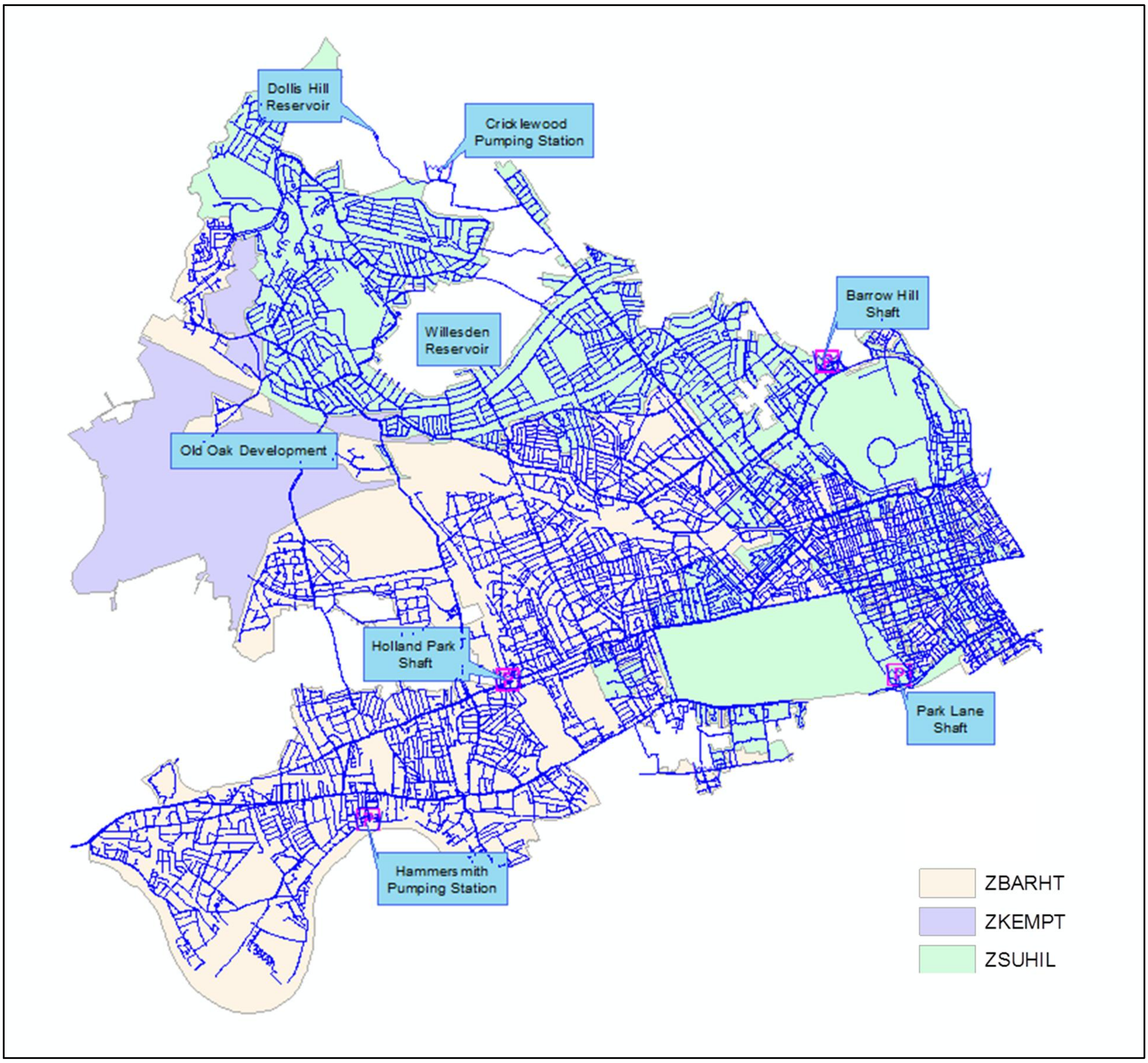


FIGURE 8 – INFOWATER MODEL OF BARROW HILL & SHOOT UP HILL

7 Model Results & Discussion

7.1 Existing Supply & Network Configuration

7.1.1 Baseline Model: Scenario A1 - 2039/40 DYPD Demand – Pumps Adjusted

The model predicts that for the 2039/40 DYCP_PD+ HR demand scenario the instantaneous peak hour minimum pressure at the proposed POC is 13.3 m.

7.2 Impact Assessment of Development

7.2.1 Impact of Development: Scenario A2 – With Old Oak Development

The model predicts that for the 2040 DYCP_PD+ HR demand scenario the instantaneous peak demand hour, minimum pressure at the proposed POC is sub atmospheric. There is a widespread impact on pressures in Barrow Hill FMZ, where a drop in pressure of approximately 7 m is seen at the Critical Press Point 290 (CPP_290) in Barrow Hill.

7.2.2 Peak Day Model with Development

The following mains reinforcement and network changes were required to provide adequate pressure within the proposed development and throughout the existing network see figures 6, 9 and 10:

- Supply the site from the Shoot Up Hill FMZ on the western side from the 30” CI main in Old Oak Lane with a 400 mm (351.2 mm ID) PE100 SDR17 main running through the site to the 16” CI Barrow Hill Main in Scrubs Lane.
- Rezone the boundary between the Barrow Hill and Shoot Up Hill zones southwards in Scrubs Lane, requiring the following valve changes:

1. 6988889 Open
2. 6988886 Closed
3. 6989458 Closed

- Lay a new 16” cross connection 3m in length between 21” CI and 16” CI mains in Barrow Hill Zone
- Extend the connection for DM18798 from the 21” Barrow Hill Zone to the 16” Shoot Up Hill ‘rezoned’ main.

7.2.3 Peak Day Model with Development plus Other Developments

The Barrow Hill pump sets at Hammersmith PS were adjusted to provide adequate pressure within the proposed development and throughout the existing network.

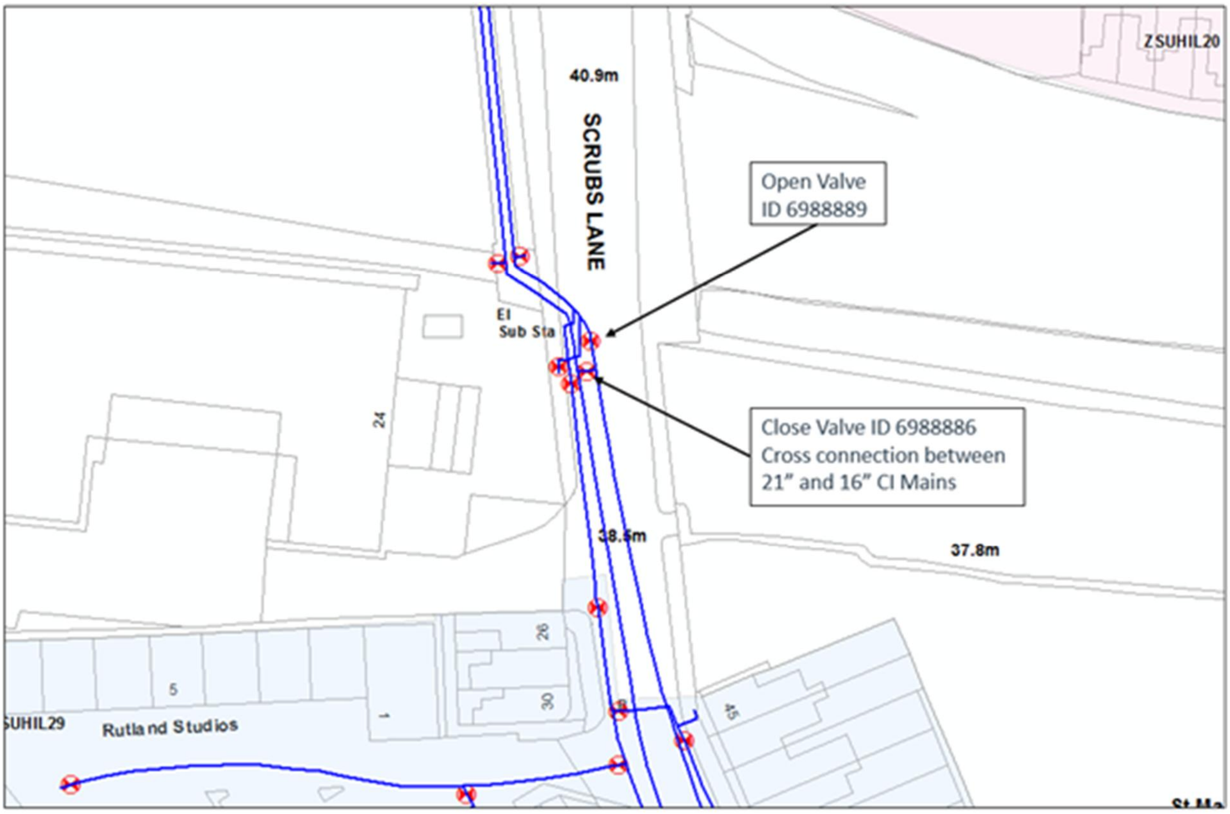


FIGURE 9 - REZONE SCRUBS LANE

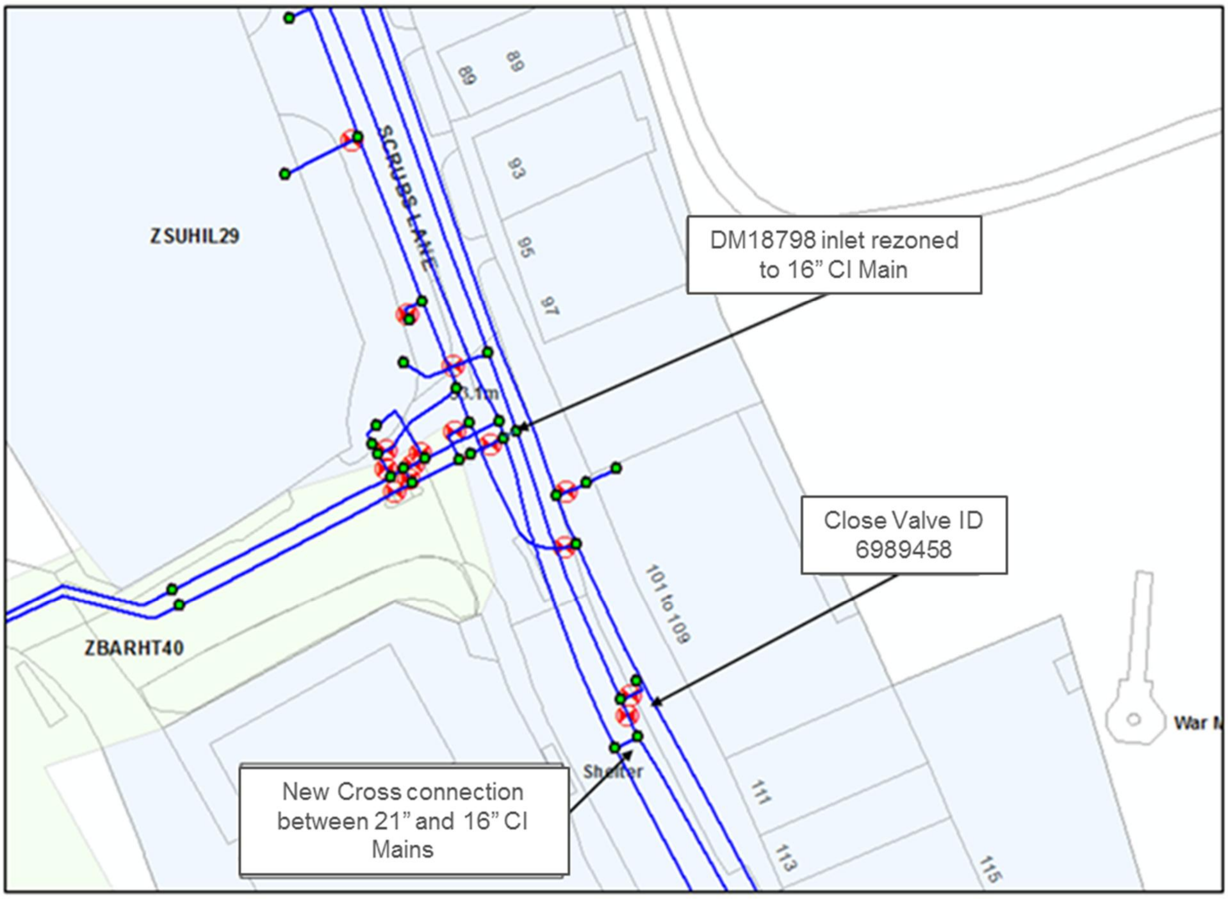


FIGURE 10 - REZONE SCRUBS LANE

7.3 Upgraded Network

7.3.1 Impact of Development: Scenario A3 – With Old Oak Development

The model predicts that for the 2040 DYCP_PD+ HR demand scenario the instantaneous peak demand hour minimum pressure at the proposed POC is 25.2 m, as the development is subjected to Shoot Up Hill FMZ pressure. Across both FMZs the pressures are within 1 m of those seen under scenario A1.

7.3.2 Impact of Development: Scenario A4 – Plus Other Developments

The model predicts that for the 2040 DYCP_PD+ HR demand scenario the instantaneous peak demand hour minimum pressure at the proposed POC is 25.19m. Pressures in the wider network are impacted on by just over 1m in Barrow Hill FMZ. The impact of all developments in Barrow Hill FMZ will need further reinforcements/enhancements to maintain the 2040 level of service.

		MODEL SCENARIO PRESSURE @ 06:15			
LOCATION	**ZONE**	**A1**	**A2**	**A3**	**A4**
POC East- D/S DM18798	ZBARHT	13.34m	0m	25.17m	25.19m
POC West – Old Oak Road	ZSUHIL	40.81m	40.74m	40.89m	40.91m
ZM14337 – Barrow Hill Shaft	ZBARHT	9.34m	3.06m	9.45m	8.28m
ZM20090 – Barrow Hill Shaft	ZSUHIL	26.8m	27.59m	27.78m	27.77m
ZM14164 – Willesden Reservoir	ZSUHIL	18.56m	18.46m	17.99m	17.99m
CPP_297	ZSUHIL	16.76m	16.76m	16.76m	16.76m
CPP_3590	ZSUHIL	32.38m	32.29m	31.84m	31.85m
CPP_290	ZBARHT	26.63m	19.63m	26.75m	25.45m

Table 3 - Predicted Pressures

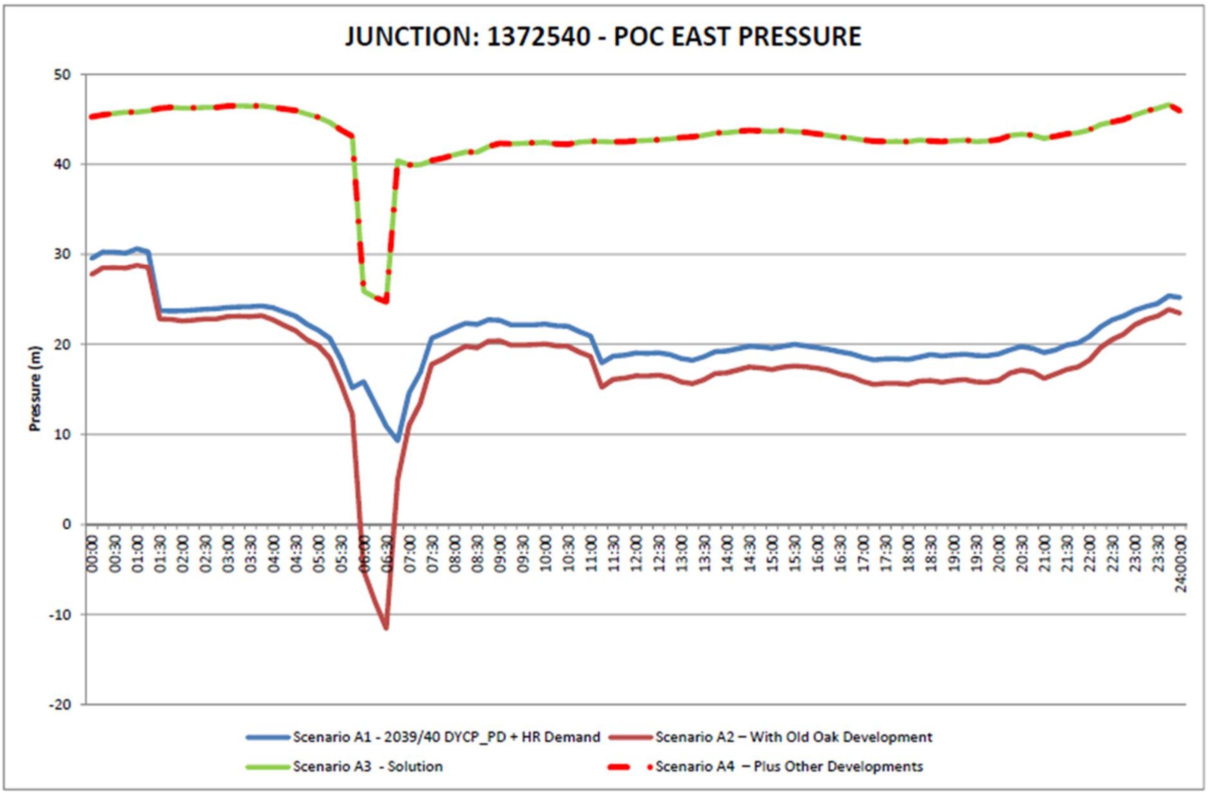


FIGURE 12 - PREDICTED PRESSURES AT THE POC EAST

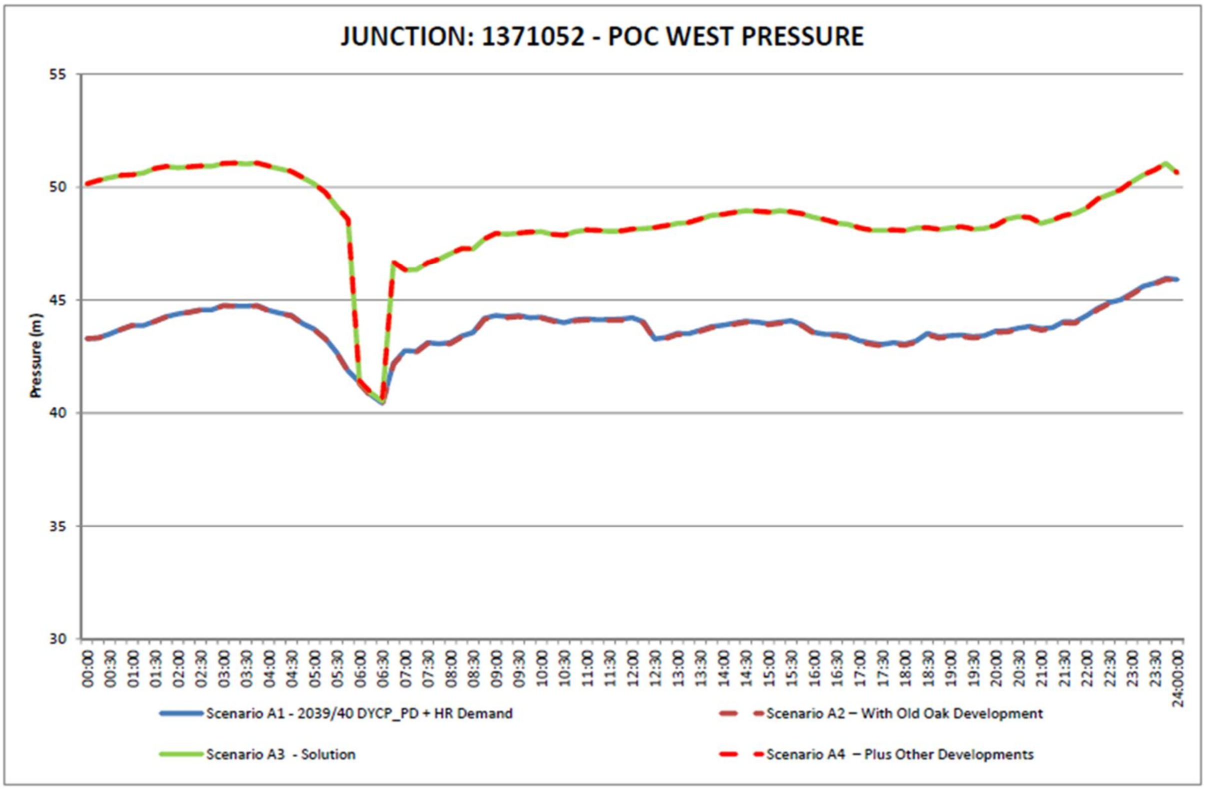


FIGURE 13 - PREDICTED PRESSURES AT THE POC WEST

8 Conclusion

In summary the model predicted that the proposed Old Oak development will have a significant impact on pressures and supply in the Barrow Hill FMZ. Network enhancements are required as pressures at the proposed POC will drop to below zero by 2040.

The supply/demand balance indicates that additional pumping will be required to feed Barrow Hill and Shoot Up Hill FMZ from Holland Park and Barrow Hill TWRM shafts, and from Hammersmith pumping station to meet the additional 9 Ml/d demand. This can be achieved by using full capacity of existing pumps.

To resolve the low pressure issues caused by the addition of the new development the following option was recommended:

- Supply the site from the Shoot Up Hill FMZ on the western side from the 30” CI main in Old Oak Lane with a 400 mm (351.2 mm ID) PE100 SDR17 main running through the site to the 16” CI Barrow Hill Main in Scrubs Lane.

- Rezone the boundary between the Barrow Hill and Shoot Up Hill zones southwards in Scrubs Lane, requiring the following valve changes:

4. 6988889 Open
5. 6988886 Closed
6. 6989458 Closed

- Lay a new 16” cross connection 3m in length between 21” CI and 16” CI mains in Barrow Hill Zone.

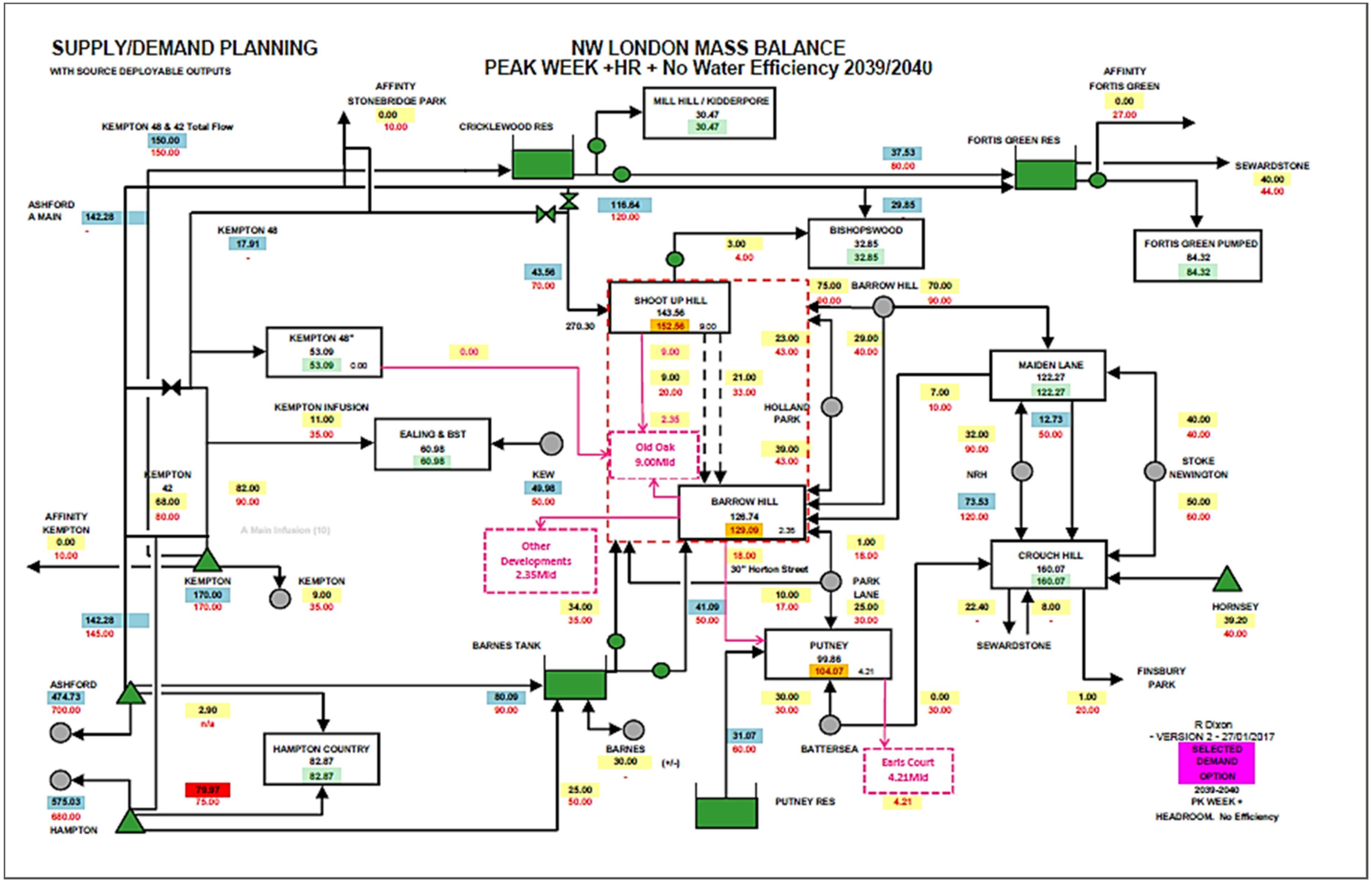
- Extend the connection for DM18798 from the 21” Barrow Hill Zone to the 16” Shoot Up Hill ‘rezoned’ main.

With the addition of further developments in Barrow Hill Zone, further strategic reinforcements or pumps may be required to maintain the 2040 level of service.

Appendix A – GLOSSARY OF TERMS

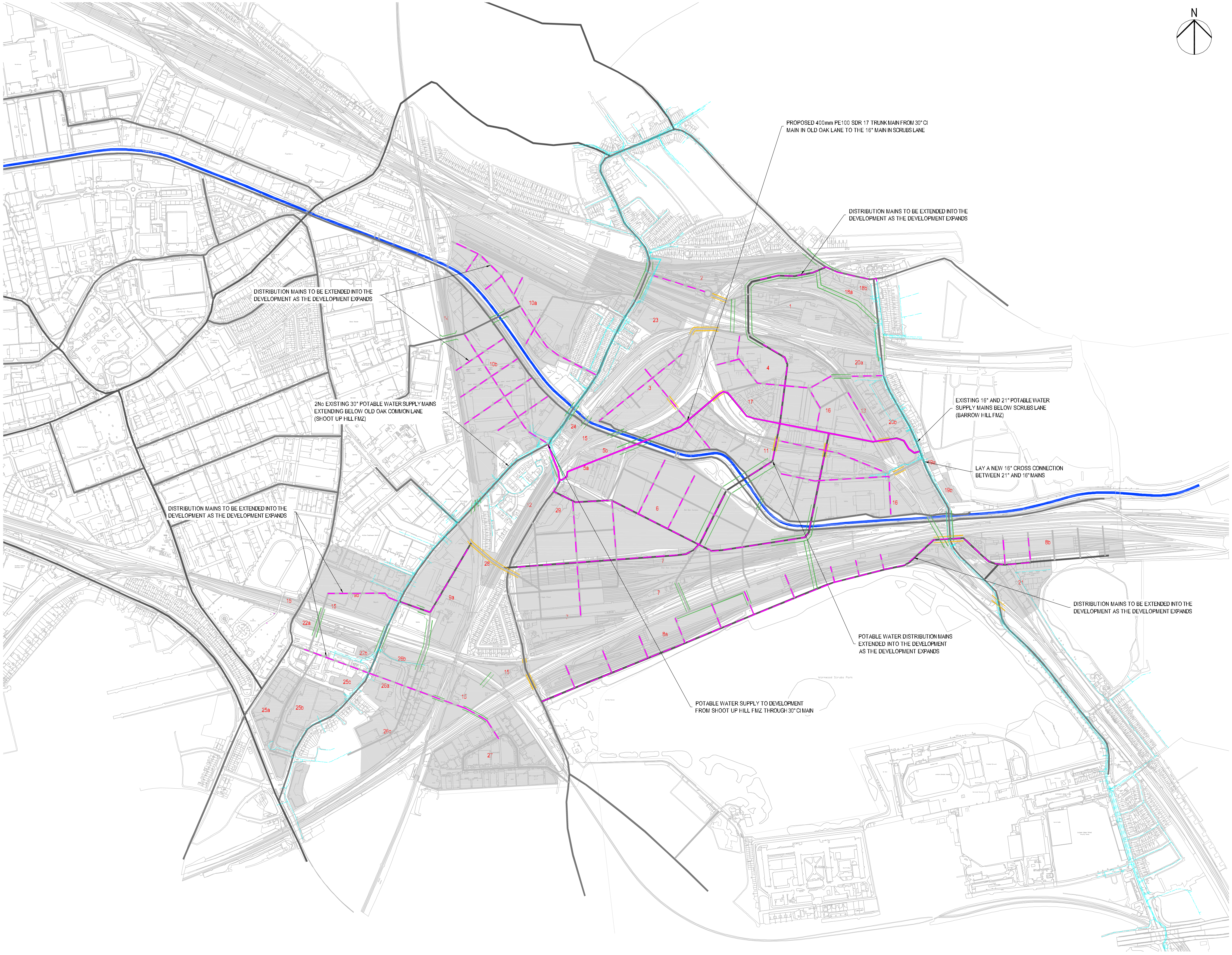
NETBASE	TWUL's Database of Network Information, with analysis and reporting functionality
OMS	TWUL's Operational Management System
PIWADIS	TWUL's District Meter Area Database
WMG	Water Modelling Group, TWUL Asset Management
ADD	Average Day Demand, based on annual consumption figure
ADPW	Average Day Peak Weak
DBV	District Boundary Valve
DIM	Distribution Input Meter
DM	District Meter
DMA	District Meter Area
d/s	Downstream
DTM	Digital Terrain Mapping
DYAA	Dry Year Annual Average
DYCP	Dry Year Critical Period
DYCP – PW	Dry Year Critical Period Peak Week equivalent of ADPW
DYPW – PD	Dry Year Critical Period Peak Day equivalent of PDPW
FMZ	Flow Monitoring Zone
GIS	Geographical Information System
GPS	Global Positioning System
GWW	Ground Water Works
l/p/d	Litres per property per day
l/s	Litres per second
LMC	Large Metered Customer
m	Metres
m/km	Meters per kilometre
m/s	Metres per second
m3	Cubic metres
Mld	Mega Litres per day
NRV	Non-Return Valve
PBV	Pressure Boundary Valve
PDPW	Peak Day Peak Week
PMA	Pressure Managed Area
POC	Point of Connection
PRVPMA	Pressure Reducing ValvePressure Managed Area
PSPRV	Pumping StationPressure Reducing Valve
PSVPS	Pressure Sustaining ValvePumping Station
SRPSV	Service ReservoirPressure Sustaining Valve
TMSR	Transmission MainService Reservoir
TWTM	Thames WaterTransmission Main
u/sTW	UpstreamThames Water
WTWu/s	Water Treatment WorksUpstream
ZBVWTW	Zonal Boundary ValveWater Treatment Works
ZMZBV	Zonal MeterZonal Boundary Valve
ZPAZM	Zonal Performance AssessmentZonal Meter
ZPA	Zonal Performance Assessment

Appendix B – Supply / Demand Balance 2040 DYCP PW + HR



Appendix K Potable Water Network Improvements

See drawing overleaf.



CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

In addition to the hazard/risks normally associated with the types of work detailed on this drawing take note of above. It is assumed that all works on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

This drawing is for preliminary purposes only and is subject to amendment during design development. UNDER NO CIRCUMSTANCES MUST THIS DRAWING BE USED FOR CONSTRUCTION PURPOSES

NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS, SERVICES AND SPECIALIST DRAWINGS AND SPECIFICATION.
2. ANY DISCREPANCIES IN DIMENSIONS OR DETAILS ON OR BETWEEN THESE DRAWINGS SHOULD BE DRAWN TO THE ATTENTION OF THE ARCHITECT AND/OR THE ENGINEER FOR CLARIFICATION.
3. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
4. DO NOT SCALE THIS DRAWING.
5. THE WATER SUPPLY STRATEGY PRESENTED ON THIS DRAWING WILL BE VERIFIED ONCE THAMES WATER COMPLETE THE STRATEGIC NETWORK IMPACT ASSESSMENT AND WHEN THE CANAL AND RIVER TRUST COMPLETE THE GRAND UNION CANAL ABSTRACTION ASSESSMENT. THESE STUDIES MAY INTRODUCE A REQUIREMENT FOR OFFSITE REINFORCEMENT WORKS.
6. THIS STRATEGY ASSUMES THAT WATER RECYCLING MEASURES WILL BE PROVIDED ON PLOT BY INDIVIDUAL DEVELOPERS.

KEY

POTABLE WATER INFRASTRUCTURE

- POT — EXISTING POTABLE WATER MAINS
- PROPOSED POTABLE WATER DISTRIBUTION MAIN
- PROPOSED POTABLE WATER TRUNK MAIN

BRIDGES, HIGHWAYS AND CONSTRAINTS

- PROPOSED BRIDGES
- PROPOSED UNDERPASSES
- MAJOR ROADS
- SECONDARY ROADS
- MINOR ROADS
- PADDINGTON BRANCH OF THE GRAND UNION CANAL

Revision Details	By / Check	Date	Suffix
REVISED TO MATCH TW IMPACT ASSESSMENT	MH / JR	31.03.17	P2
FIRST ISSUE	MH / JR	23.12.16	P1

Purpose of issue

DRAFT

Client

OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title

OLD OAK COMMON

Drawing Title

OLD OAK COMMON POTABLE WATER SUPPLY STRATEGY

Designed	Drawn	Checked	Approved	Date
JR	MH	BM	BM	DEC 2016

AECOM Internal Project No.	Suitability
60495203	
Scale @ A1: 1:5000	

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Drawing Number: OPDC-AEC-XX-XX-DR-UT-00020 | Rev: P2

SCALE 1:5000 (0 100 200 300 400 500m)

Appendix L Canal & River Trust Discharge Assessment

See overleaf.

OLD OAK COMMON SWD INITIAL FEASIBILITY ASSESSMENT

21 February 2017

Client:	Utilities Team
Contact:	Nick Pogson
Issue:	External
Date of Issue:	21st February 2017
Prepared By:	S Richards Sarah Richards (Hydraulic / Hydrological Modeller)
Checked By:	M Wells Mat Wells (Principal Hydrologist)
Authorised By:	Adam Comerford (National Hydrology Manager)

1. OVERVIEW

Water Management has been asked by the Utilities team to assess the feasibility of a new surface water discharge into the Paddington Arm of the Grand Union Canal, located within a long 43 km pound. The “Long Pound” functions as a reservoir to feed water through Lock 1A Hampstead Road Lock to the Regents Canal and through Lock 90 Hanwell Top Lock to the Norwood flight. There is only one principal source of water to the pound, namely lockage and bypass flows at Lock 89, Cowley Lock. The proposed site is Old Oak Common (NGR TQ 22122 82239), which will be redeveloped to accommodate a mixed use development with approx. 27,000 residential dwellings and 814,000 m^2 of commercial floor space. The proposed site is approximately 24 km along the canal from Lock 89 Cowley, and 8 km above Lock 1A Hamsptead Road Lock.

AECOM (the external client) estimates the catchment size to be 26.55 ha and that the maximum un-attenuated post development peak discharge rate is 10.7 m^3/s (1:100 + 20% CC + 10 % UC). Greenfield runoff is estimated to be 0.1 m^3/s. They acknowledge that the calculations are based on limited information, therefore no detailed design of the site’s drainage systems or the duration of various flows have been modelled at this stage. Both are clearly important when evaluating the ability of the canal to accommodate an increase in discharge.

The purpose of this assessment is to evaluate the viability of putting flood waters from the development site to the canal, and to appraise potential engineering measures that could help to accommodate an increase in flow, (including a rough estimation of costs). Although the initial calculations provide some indication of potential flood mitigation for a range of flows, for a development of this scale, such mitigation can only be derived from detailed hydraulic modelling. This is beyond the scope of this initial assessment.

The initial findings conclude that there are several existing structures in the Long Pound, as well as a few downstream, that may be able to accommodate additional flows from the site. The construction of a new by-weir downstream is also a possibility. The exact scale of the flows which can be accommodated (and associated costs) will be dependent on the type of mitigation measures carried out. The feasibility of the proposed schemes will need to be appraised in a detailed hydraulic assessment.

2. RISK REGISTER ASSESSMENT (STANDARD CRT METHOD)

A bespoke spreadsheet “risk register” tool is used by the Trust to assess if a new surface water discharge is acceptable. It calculates if an increase in the maximum peak discharge causes an unacceptable increase in flood risk. Flood risk can be mitigated by extending waste flood structures/weirs. The amount of additional weirage required to reduce the risk to an acceptable level can also be estimated with this tool.

Table 1 summarises the amount of additional weirage that would be required to accommodate a range of peak maximum flows at Old Oak Common:

Table 1: Output of CRT "Risk Register" analysis showing the amount of additional weirage required to mitigate the flood risk caused by the increase in maximum peak discharge at Old Oak Common

Maximum discharge rate m^3/s	Additional Weirage Required (m)
0.1	2
0.5	10
1	20
1.5	30
2	40
2.5	50
5	100
10.7	210

Even for the lowest amounts modifications to the canal flow regime are required to mitigate the flood risk.

The scale of mitigation required for a maximum peak discharge of 10.7 m^3/s is higher than the current total amount of fixed weirs in the Long Pound (144m, see below).

The above figures should be considered indicative only, and have been calculated using a conservative approach. Critically, this feasibility does not take into account:

(i) Flood storage (along the 43 km canal pound)
(ii) Hydraulic gradients between flood discharge to flood weirs
(iii) The duration of the storm being considered (i.e. flood volume)

Considerations of these elements are imperative when considering a development of this scale, and can only be undertaken with detailed hydraulic modelling. The detailed modelling of the canal to accommodate these considerations (and reduce the scale of mitigation works) is estimated to be of the order of £20k.

3. POTENTIAL ENGINEERING WORKS TO ACCOMMODATE ADDITIONAL FLOW

Various engineering measures may mitigate the impact of the additional flow from the development site. As well as typical fixed side weirs these include:

- Crenulation of existing waste weir crests within the pound
- Crenulation of by-weir structures downstream (Regents Canal)
- Construction of new structures downstream e.g. a new byweir or sluice at Lock 1A Hampstead Road Lock
- Installation of tilting gates on existing waste weir crests

3.1 Crenulation of existing weir crests

The Long Pound where Old Oak Common is located already has a total of 144m of weirage, provided by 6 waste weir structures of various sizes and designs. Photos of 4 of the weirs can also be seen in the appendix (Figures 1-4). Figure 7 (see appendix) shows where these structures are located relative to the development site.

In 2013 CRT accommodated a new discharge into the Regents Canal by crenulating the crests of 8 transverse byweir structures, for an example of these works see Figure 5 in the appendix. These modifications increased the volume of discharge that could be accommodated by around an additional 50%. The costs of these works was in the region of £600,000.

None of the 6 waste weirs in the long pound have been crenulated as yet, so there is a possibility that additional flow from Old Oak Common could be accommodated by crenulating part or all of the crest of one or more of these structures. A detailed hydraulic assessment of the weirs is required to determine precisely how much additional flow could be accommodated, (as this is determined by the length of the crest that is crenulated, the depth of the crenulation, and the structural readiness of the weir to carry additional flows from the canal to the receiving watercourses). Costs may vary considerably from structure to structure, depending on the level of engineering works required. Consent from the Environment Agency to discharge higher volumes of flood water to the receiving water course will also be required.

It may also be possible to crenulate 3 downstream by-weir structures downstream at Lock 2 Hawley (NGR TQ 28814 84170), Lock 3 Kentish Town (NGR TQ 28900 84151) and Lock 4 St. Pancras Locks (NGR TQ 29925 83597), which are located between 8.4 –9.7 km downstream of Old Oak Common. However, the amount of additional flow that be accommodated further downstream is limited. Hydraulic modelling undertaken for the 2013 works referenced above confirmed that the bottom of the Regents Canal will only be able to receive an additional 0.22 m^3/s from new upstream discharges.

3.2 Construction of new flood mitigation structures

At present there is no by-weir structure at Hampstead Road (Camden) Lock (NGR TQ 28678 84079), where (despite limited physical space), there may be potential to construct one. Although structurally there may also be potential to construct a sluice the restriction of downstream flows to 0.22 m^3/s means that further works would also need to be undertaken downstream to benefit from this. The design and capacity of the by-weir structure could be explored further in a more detailed hydraulic study. It is known that there is limited space for construction works at this site, so it is anticipated that a significant sized pipe or culvert will need to installed if a byweir is constructed, and that there will be restricted access for plant and materials. Due to these constraints a very rough estimation of the costs of the works (based on general knowledge of the site, rather than a site survey) is £500,000. More precise costs for such works can only be estimated after detailed hydraulic modelling is undertaken.

3.3 Installation of Tilting Gates

To accommodate high flow rates and volumes crenulation alone is unlikely to be a feasible solution. Installing tilting weir gates at one of more of the existing flood weir structures in the long 43 km pound is a flexible solution that would allow much greater volumes of discharge to be accommodated. For example, Bulls Bridge weir (the lowest and controlling weir for the pound) is divided in to 9 sections by concrete pillars, so gates could be installed in some of all of the sections. The Trust has already installed tilting gates on structures on the Gloucester & Sharpness Canal, for example an 8m broad crest weir was completely replaced by two 4m titled gates at Purton in 2007 (see Figure 6 in the appendix). Costs include the hardware, installation of electrical equipment to control the gates remotely, and there are also operation and maintenance costs. For the above project the costs of the initial installation were c. £310,000 in 2007, and it is estimated that the same project would cost c.£390,000 in 2017. The weir was installed at a rural site with unrestricted access, however additional costs may be incurred for similar works in more built up. Operating and maintenance costs are estimated to be c.£500, however these costs can vary from site to site.

Detailed hydraulic modelling of suitable flood weir structures will need to be undertaken to determine how much additional flow could be accommodated if tilting gates are installed.

4. WATER QUALITY – ENVIRONMENTAL APPRAISAL

The development site is to be comprised of 27,000 residential dwellings and 814,000m^2 of commercial floor space. There are also to be a number of energy centres (details not submitted).

4.1 Operational phase of the development

a. Under our Local Operational Control (LOC) for Discharges to CRT Waterways, the operational phase of the development would be classified as being of medium risk, given its scale and residential/commercial nature. The nature of the commercial activities is not described in the application and I have assumed that there is the potential for certain commercial activities to involve goods vehicle parking and/or vehicle manoeuvring. For medium risk sites, CRT requires that a Class 1 oil interceptor be installed prior to each discharge point into the waterway.

b. We require the applicant to adhere to the Environment Agency's PPG3 guidance note on oil separators: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290142/pmho0406biyl-e-e.pdf . Although PPG3 has been withdrawn by the EA, we still regard it as constituting best practice, and therefore require prospective dischargers to CRT waterways to adhere to it. The applicant needs to ensure that the separators are sized in accordance with PPG3 and the applicant also needs to account for how silt storage is to be provided for.

c. The applicant needs to provide sufficient access points in the design to allow for inspection and cleaning of the internal chambers.

d. The applicant must undertake to label the oil separator(s) as per PPG3 and to show their presence on drainage plans.

e. The applicant needs to submit a maintenance procedure for the oil separator(s) that encompasses the maintenance requirements of PPG3.

f. The application states that measures will be provided to prevent pathways between the canal and potential sources of existing ground contamination, as surface water drainage systems and Sustainable Drainage Systems will be lined. This undertaking should form part of any agreement.

4.2 Demolition & construction phase of the development

a. The application states that a ground investigation has not yet been undertaken, as this initial enquiry is provided to determine whether it will be feasible to discharge surface water to the Grand Union Canal. In the absence of any data to demonstrate that the soil and groundwater on-site is **not** contaminated, a precautionary approach is required. This will mean that no discharge of collected rainwater, rainwater run-off or extracted groundwater/perched water from dewatering works etc. will be accepted into the CRT waterway during construction works i.e. any temporary surface water drainage system in place during construction works should not discharge to the CRT waterway.

5. SUMMARY

This assessment concludes that it may be possible to accommodate additional surface water discharge from the Old Oak Common development site into the Paddington Arm, however the amount of additional discharge that is feasible can only be determined by undertaking in-depth hydraulic modelling. Various engineering works could mitigate the flood risk from the additional discharge, ranging from the crenulation of weir crests to the installation of tilting weir gates. The Trust has previous experience and detailed knowledge of how to successfully undertake both types of works. There are several existing structures in the Long Pound where Old Oak Common is located that have the potential to be modified. The impact of building a new structure or modifying by-weirs along the Regents Canal is also possible, but at present limited by the amount of additional discharge that can be accommodated further downstream.

The scale of mitigation for this site would be without precedent compared to any discharge that have previously been accepted across the Trust’s 2,000 mile network. An estimation of the maximum post development peak discharge has been provided, but this is based on limited information and will need refining once details such as the number of discharge points are known. Detailed hydraulic modelling will help to determine the amount of additional discharge that the proposed engineering works can accommodate, and allow more accurate cost estimations to be provided. The detailed study should also take in to account the impact of additional flows on the receiving watercourses beyond the Trust’s network. It is estimated that a detailed modelling of the canal would be of the order of £20k. This should provide the detail of the mitigation works required for the range of discharges being considered and would include due consideration of the considerable attenuation that may be provided by the 43km canal pound.

APPENDIX

I. **Figure 1: Court Lane Road Waste Weir**

II. **Figure 2: River Pinn Waste Weir**

III. **Figure 3: Bulls Bridge Weir**

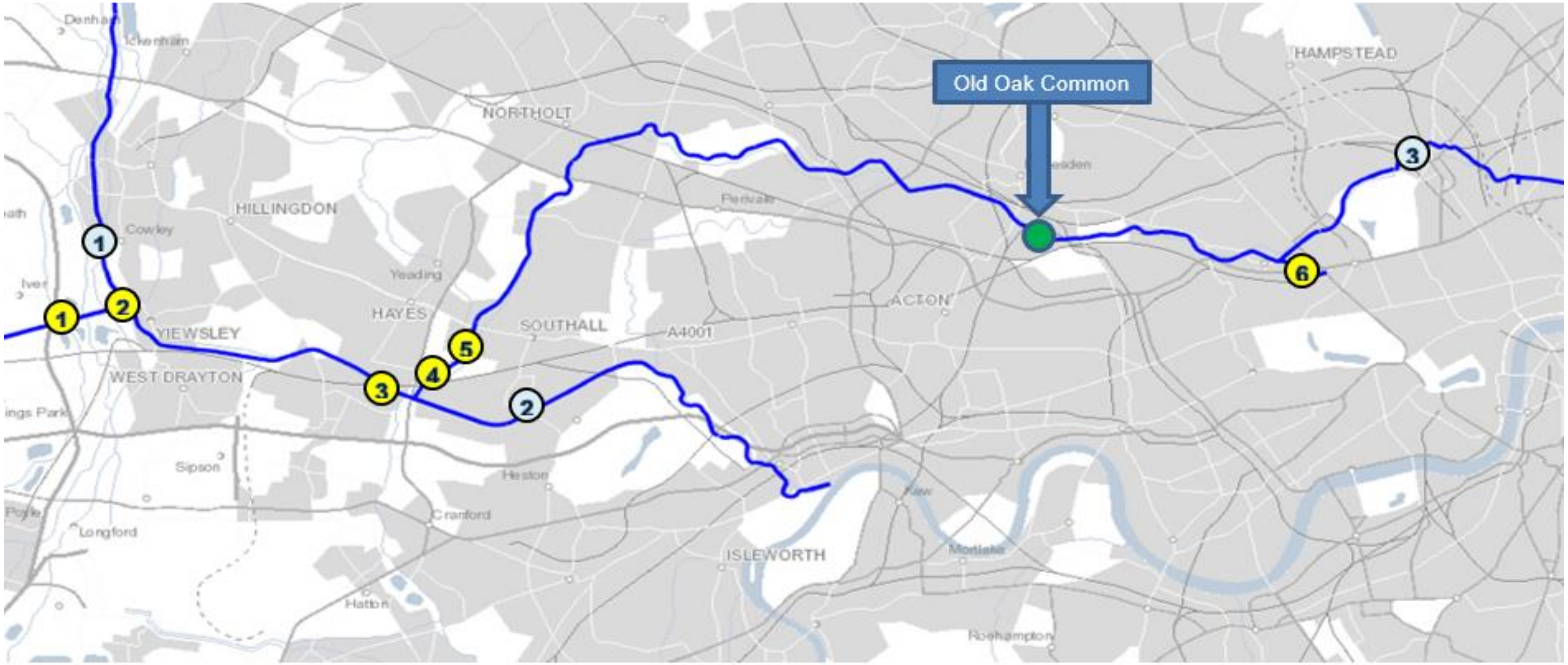
IV. **Figure 4: Southall Fixed Weir**

V. **Figure 5: Crenulation of a transverse by-weir crest on the Regents Canal**

VI. Figure 6: Tilting weir gate – Purton Weir on Gloucester & Sharpness Canal

Canal & River Trust

VII. Figure 7: Map of the 43 km pound where Old Oak Common is located, (including flood weir structures and lock flights)

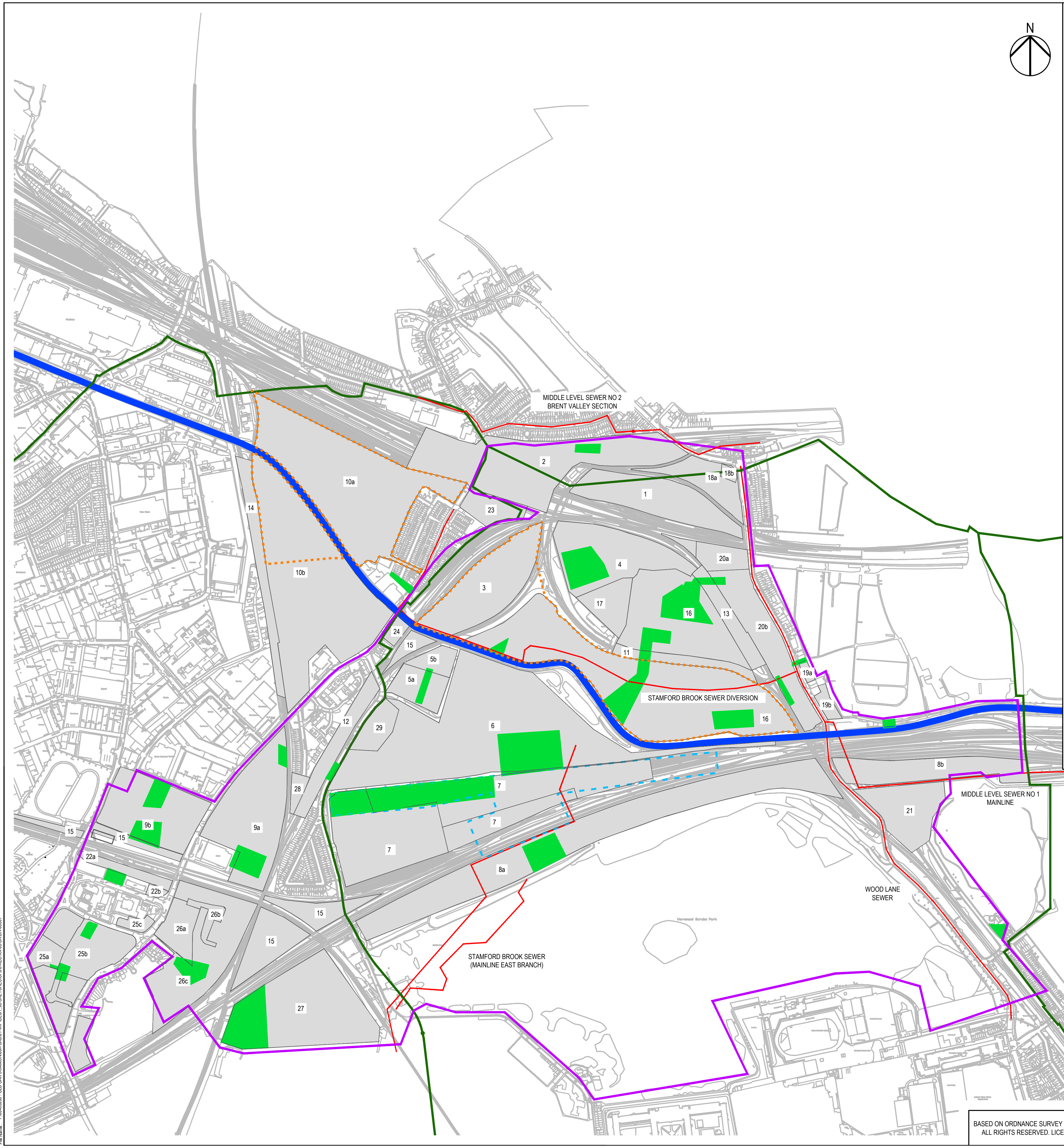


(1) Court Lane Road Weir (NGR TQ 04367 80661), 13 m crest (2) River Pinn Weir (NGR TQ 05560 80896), 27 m crest
(3) Bulls Bridge Weir (NGR TQ 10456 79226), 30 m crest (4) Southall Fixed Weir (NGR 11546 79875), 55 m crest
(5) Brick Weir (NGR 11608 80291), 6 m crest (6) Travis Perkins Weir & Sluice (NGR TQ 26447 81696), 13 m crest

(1) Cowley Lock (NGR TQ 05156 82258) (2) Hanwell Lock (NGR TQ 13688 79371) (3) Hampstead Rd Lock, top of Regents Canal (NGR TQ 28667 84076)

Appendix M Surface Water Drainage

See overleaf.



PLOT NAME	PLOT No.	TOTAL PLOT AREA (ha)	PERMISSIBLE RUN OFF RATE WITHIN WHOLE SITE BASED ON 1:100 YEAR GREENFILED RUNOFF RATE (l/s)	APPROXIMATE VOLUME OF ATTENUATION STORAGE REQUIRED WITHIN SITE (m^3)
LOROL DEPOT	1	3.19	15.50	2639
WILLESDEN JUNCTION	2	6.93	33.60	5734
POWERDAY	3	3.73	18.1 *	3082 *
EMR	4	3.73	18.10	3083
GENESIS - SOUTH	5a	1.12	5.40	929
GENESIS - NORTH	5b	0.59	2.90	487
CROSSRAIL DEPOT	6	13.03	63.30	10779
HS2 STATION OSD TRIANGLE GWML OSD	7	11.17	54.20	9239
IEP	8a	8.72	42.30	7214
NORTH POLE EAST	8b	2.62	12.70	2166
SHIELD (HS2 WORKSITE)	9a	4.71	22.90	3899
VICTORIA ROAD BOX (HS2 WORKSITE)	9b	3.59	17.40	2967
WILLESDEN EURO	10a	8.82	42.8 *	7296 *
NORTHERN HS2 WORKSITE	10b	9.83	47.7 *	8129 *
HYTHE ROAD STATION	11	0.83	4.10	689
OOC LANE STATION	12	1.38	6.70	1142
TERMINATING PLATFORMS	13	1.01	4.90	832
DUDDING HILL LANE	14	1.51	7.30	1248
LAND LOCKED SITES	15	3.43	16.70	2840
CAR GIANT	16	15.64	75.9 *	12939 *
LBHF	17	1.12	5.40	925
HARROW ROAD	18a	1.39	6.80	1151
HARROW ROAD - 2 SCRUBS LANE	18b	0.12	0.60	100
SCRUBS LANE EAST / NORTH KENSINGTON GATE NORTH	19a	0.12	0.60	96
SCRUBS LANE EAST / NORTH KENSINGTON GATE SOUTH	19b	0.28	1.40	229
SCRUBS LANE WEST	20a	0.76	3.70	627
SCRUBS LANE WEST	20b	3.02	14.70	2499
MITRE SITE	21	2.22	10.80	1839
NORTH ACTON (GRASS VERGE AND OSD)	22a	0.55	2.70	458
HOLBROOK HOUSE	22b	0.12	0.60	95
PARK ROYAL LINKS	23	0.96	4.70	793
CANAL SITE	24	0.24	1.20	199
6 PORTAL WAY	25a	1.55	7.50	1287
CARPHONE WAREHOUSE	25b	1.92	9.30	1589
THE PORTAL	25c	0.25	1.20	208
PERFUME FACTORY	26a	1.01	4.90	838
MONARCH HOUSE	26b	0.37	1.80	304
SEGRO	26c	4.05	19.70	3348
WESTWAY INDUSTRIAL ESTATE	27	6.03	29.30	4984
MIDLAND GATE TERRACE	28	0.28	1.40	232
TOTAL		**131.94**	**640.90**	**109134**

NOTE:- * - PEAK DISCHARGE RATE MAY BE INCREASED SUBJECT TO AGREEMENT FROM THE CANAL AND RIVER TRUST

TABLE DEFINING PERMISSIBLE SURFACE WATER DISCHARGE RATES AND ATTENUATION VOLUMES

CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

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SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

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NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS,SERVICES AND SPECIALIST DRAWINGS AND SPECIFICATION.
2. ANY DISCREPANCIES IN DIMENSIONS OR DETAILS ON OR BETWEEN THESE DRAWINGS SHOULD BE DRAWN TO THE ATTENTION OF THE ARCHITECT AND/OR THE ENGINEER FOR CLARIFICATION.
3. DO NOT SCALE THIS DRAWING.
4. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH DRAWING REFERENCES OPDC-AEC-XX-05-SK-DR-00002 AND 00003 WHICH SHOW TYPICAL DETAILS OF SUSTAINABLE DRAINAGE SYSTEMS

KEY

- OPDC OLD OAK COMMON BOUNDARY
- LONDON BOROUGH BOUNDARY
- DEVELOPMENT AREAS
- 2 PLOT REFERENCE NUMBER
- FUTURE AREA FOR OLD OAK COMMON RAILWAY STATION
- PADDINGTON BRANCH OF THE GRAND UNION CANAL
- PROPOSED NEW OPEN SPACES WHICH HAVE POTENTIAL TO ACCOMMODATE STRATEGIC SUDS
- EXTENT OF SITE WITH POTENTIAL TO DISCHARGE SURFACE WATER TO THE GRAND UNION CANAL BY GRAVITY SUBJECT TO CONSENT FROM THE CANAL AND RIVER TRUST
- EXISTING COMBINED SEWERS WHICH FORM OUTFALL FOR ATTENUATED RUNOFF FROM DEVELOPMENT PARCELS THAT DO NOT DISCHARGE SURFACE WATER TO THE GRAND UNION CANAL

Revision Details	By / Check	Date	Suffix
FIRST ISSUE	MH / JR	24.02.17	P1

Purpose of issue
FOR INFORMATION

Client
OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title
OLD OAK COMMON

Drawing Title
SURFACE WATER DRAINAGE PERMISSIBLE RUNOFF RATES AND ATTENUATION STORAGE VOLUMES

Designed	Drawn	Checked	Approved	Date
JR	MH	JR	BM	24.02.17

AECOM Internal Project No.: 60495203
Suitability: FOR INFORMATION
Scale @ A1: 1:5000

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Drawing Number: OPDC-AEC-XX-05-SK-DR-00001
Rev: P1

1 : 5000
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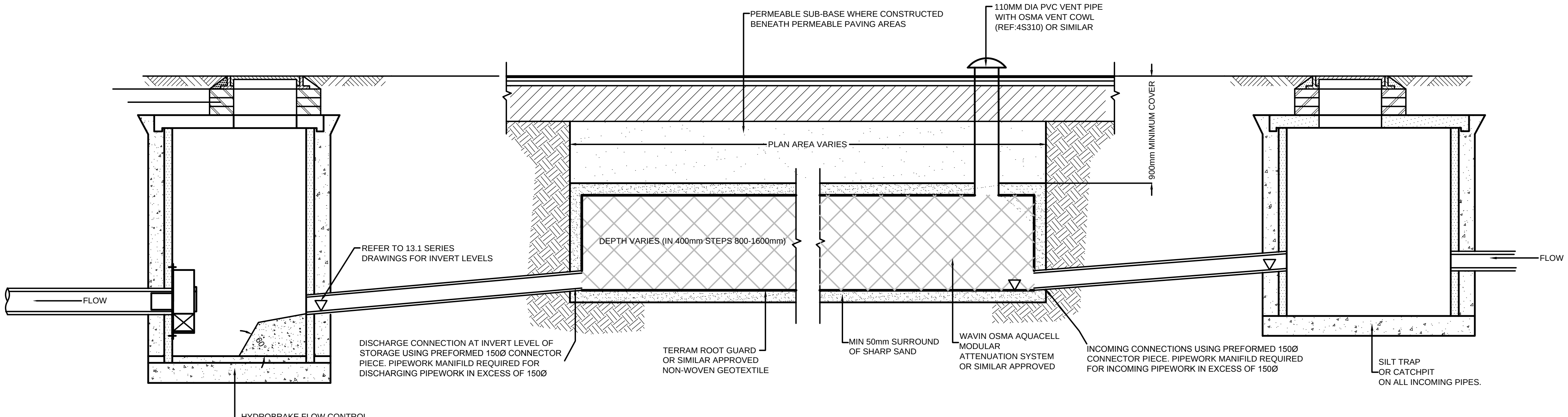
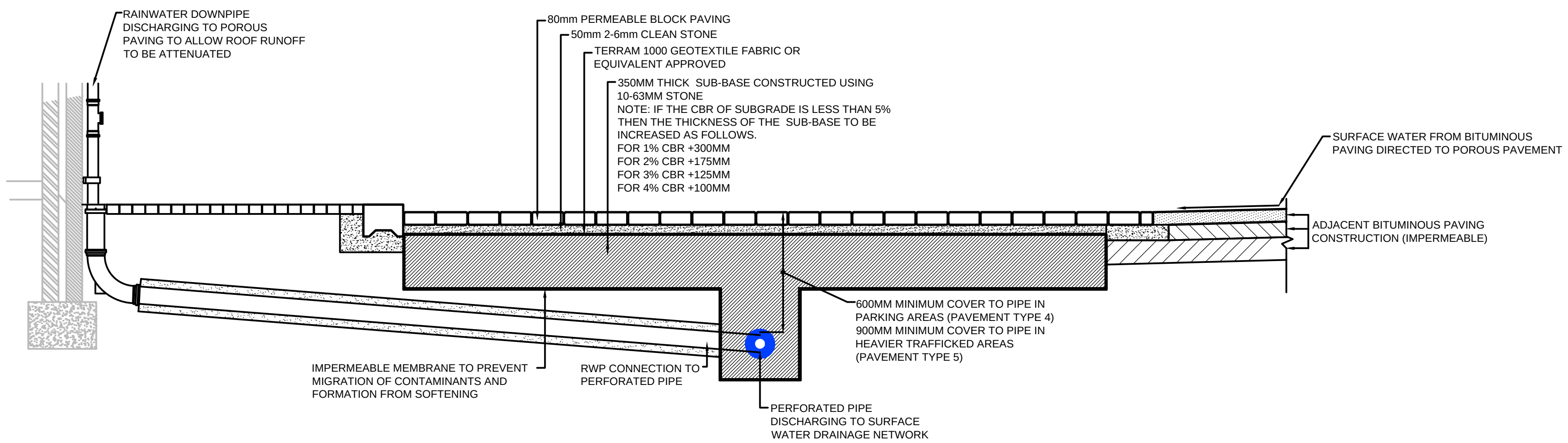


TYPICAL DETAIL SHOWING UNDERGROUND GEOCECULLAR STORAGE



TYPICAL DETAIL SHOWING POROUS PAVEMENT CONSTRUCTION

CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

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Revision Details	By / Check	Date	Suffix
FIRST ISSUE	MH / JR	24.02.17	P1

Purpose of issue

FOR INFORMATION

Client

OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title

OLD OAK COMMON

Drawing Title

TYPICAL DETAILS OF SUITABLE SUSTAINABLE DRAINAGE SYSTEMS SHEET1

Designed	Drawn	Checked	Approved	Date
JR	MH	JR	BM	24.02.17

AECOM Internal Project No.	Suitability
60495203	S1-CO-ORDINATION
Scale @ A1: N.T.S	

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Drawing Number: OPDC-AEC-XX-05-SK-DR-00002

Rev: P1

Plot Date : 3/31/2017 9:26 PM
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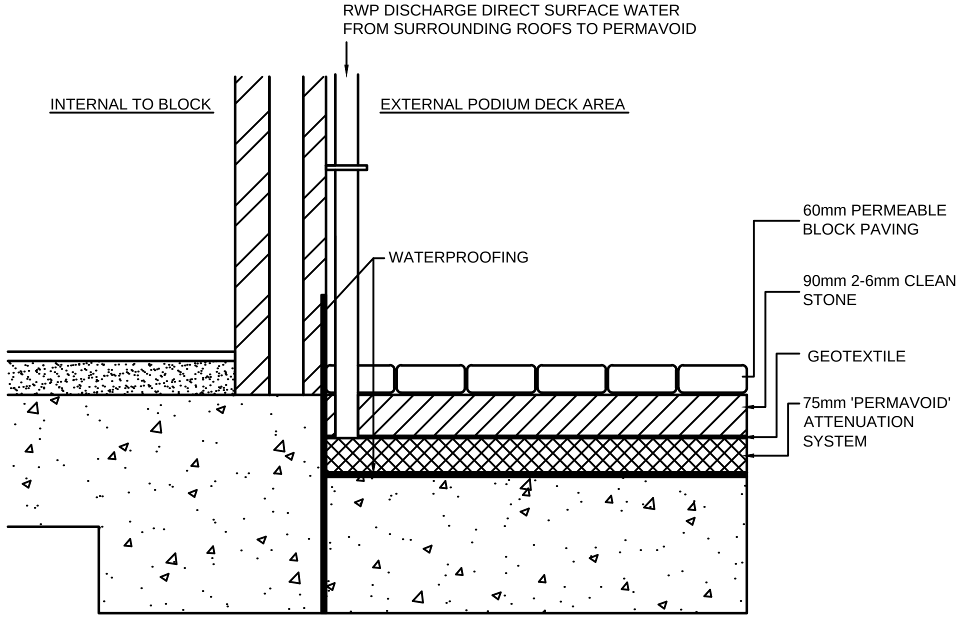
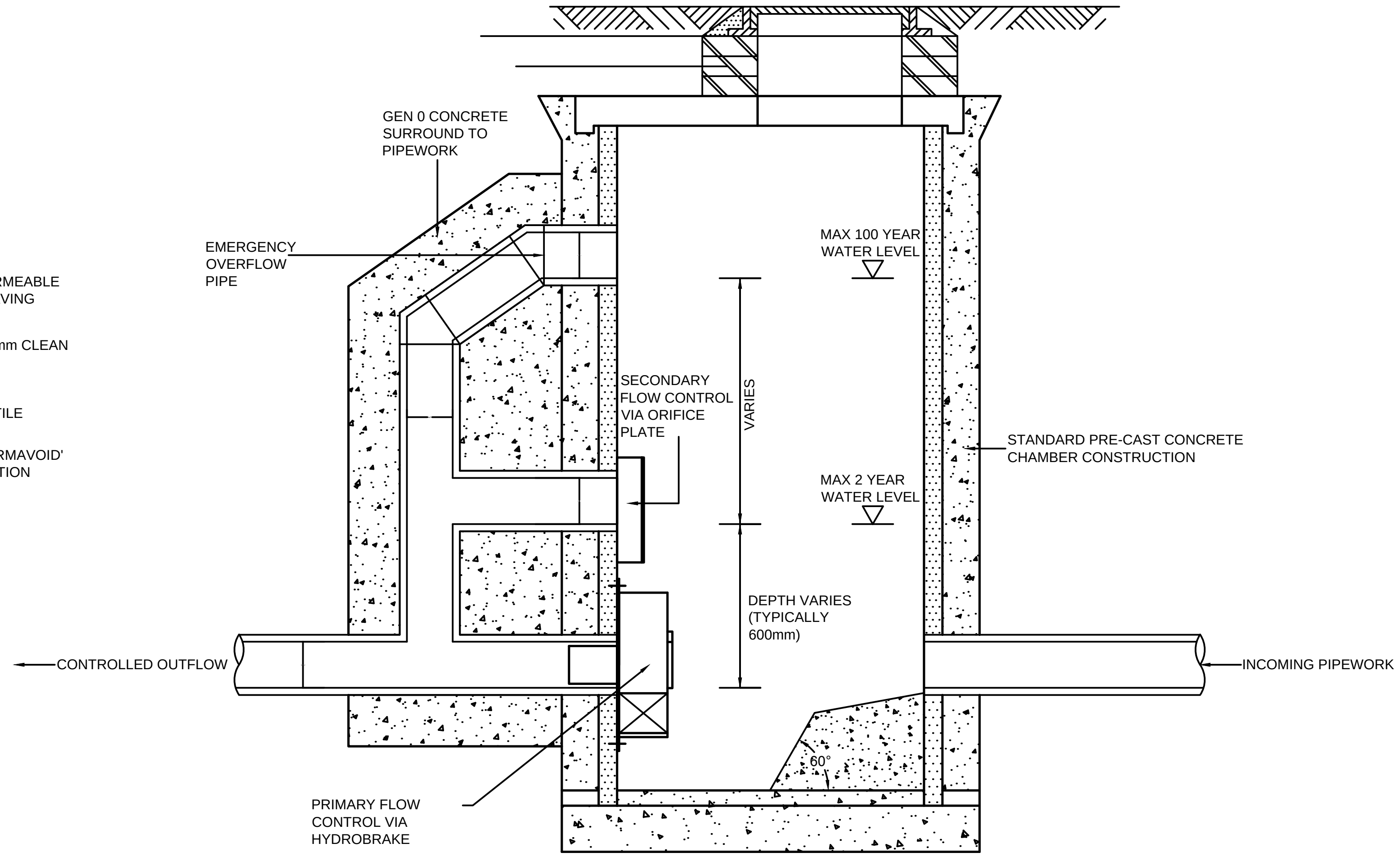


TYPICAL DETAIL SHOWING PERMAVOID STORAGE PROVIDED ON PODIUM DECK TO ALLOW SURFACE WATER TO BE ATTENUATED AT SOURCE



TYPICAL COMPLEX FLOW CONTROL DETAIL REQUIRED DOWNSTREAM OF UNDERGROUND STORAGE TO RESTRICT THE PEAK SURFACE WATER DISCHARGE TO GREENFIELD RATES

CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

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Revision Details	By / Check	Date	Suffix
FIRST ISSUE	MH / JR	24.02.17	P1

Purpose of issue

FOR INFORMATION

Client

OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title

OLD OAK COMMON

Drawing Title

TYPICAL DETAILS OF SUITABLE SUSTAINABLE DRAINAGE SYSTEMS SHEET 2

Designed	Drawn	Checked	Approved	Date
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AECOM Internal Project No.	Suitability
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Drawing Number	Rev
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