Summary Report

Heating Options and Outline Services Proposals

St Mary’s Church

Ely

Illuminous
+44(0)115 922 4056
www.illuminousconsult.com
Eco Innovation Centre
CityRoad, Peterborough
PE1 1SA

Directors
Michael Barham BEng (Hons), MSc, CEng, MCIBSE, MSLL
Joe GaylorMCIBSE, LCEA, LCC
Alison Holman BA (Hons), MA (Cantab)

Version: 3:
Update following Client Review. Lighting and power services proposals added
Date: 09 March 2020

Project 19-ALA05

Heating Options and Outline Services Proposals

St Mary's Church, Ely

19-ALA05

Introduction

Illuminous Consulting have been commissioned to review and present summary options for heating St Mary's Church as part of a planned transformation project.

A brief survey to inform this appraisal was carried out on 2 July 2019, with an initial options report presented in July 2019 which built on the outline recommendations from earlier appraisals by Dr Colin Bemrose (October 2016).

This report provides an update to address a number of specific queries from the Standing Committee of the Church Council. These were discussed as part of the review of the July 2019 report at a meeting on the 18 December 2019, and amongst these discussions arose a number of key issues:

1. The viability, in detail, between retaining gas boilers to serve the new heating system, and replacing with air source heat pumps. The response to this required further cost study and analysis – the outcomes of which are summarised in this report.
2. The performance, reliability and suitability of air source heat pumps for church buildings, including exemplar projects where in-use data can be reviewed. A number of responses to this were discussed and largely concluded (eg; feedback from and a list of recent projects to either visit or review data for), although more design information to conclude the siting, installation and protection (both spatial to maintain efficient operation and acoustic for noise mitigation) was also deemed necessary and technical proposals have been developed alongside this report.
3. The suitability and operation of underfloor heating, and requirements for supplementary and ancillary heating. Again, further design development was necessary to establish coordinated technical proposals for heating each space within the transformation project. These proposals are summarised in this report and illustrated on a technical proposal drawing.
4. The viability and suitability of solar photovoltaic panels within the proposals – both as a stand-alone initiative, and in support of other energy initiatives (heat pumps). The outcomes of further study into this are given in this report.

Technical design proposals have been developed following this review – with the aim of both communicating the heating proposals in more detail, and providing more robust modelling data to inform a viability case for the heating and renewables options.

The information, findings and recommendations given in this report are for the exclusive use of the Diocese of Ely, the Standing Committee of the Church Council of St Mary's and their appointed agents for the purposes of developing design proposals for this particular building. No responsibility will be taken for the accuracy or reliability of any information, findings or recommendations given in this report if used for any other purpose or by any other party.

Contents

Heating Options and Outline Services Proposals

St Mary's Church, Ely

19-ALA05

Summary

This report updates previous outline assessments comparing gas boilers and air source heat pumps to heat St Mary's Church as part of the planned Transformation Project.

The heating proposals include a mix of underfloor heating and trench heaters within the main worship space, and conventional radiators and convectors providing supplementary and local heating. Fan convectors within the meeting room (bell ringing room) and creche will also maintain fresh air requirements for these spaces. An illustration of the basic heating needs and concepts is given (right).

The church is currently served with mains gas and heated by gas fired boilers. This is the baseline from which an alternative air-source heat pump system has been assessed.

The air source heat pump system will come with a capital premium of £47,200. Without any incentives, this capital is likely to be recovered within a reasonable expected total system life (25 years), but will not present any reasonable return on the investment.

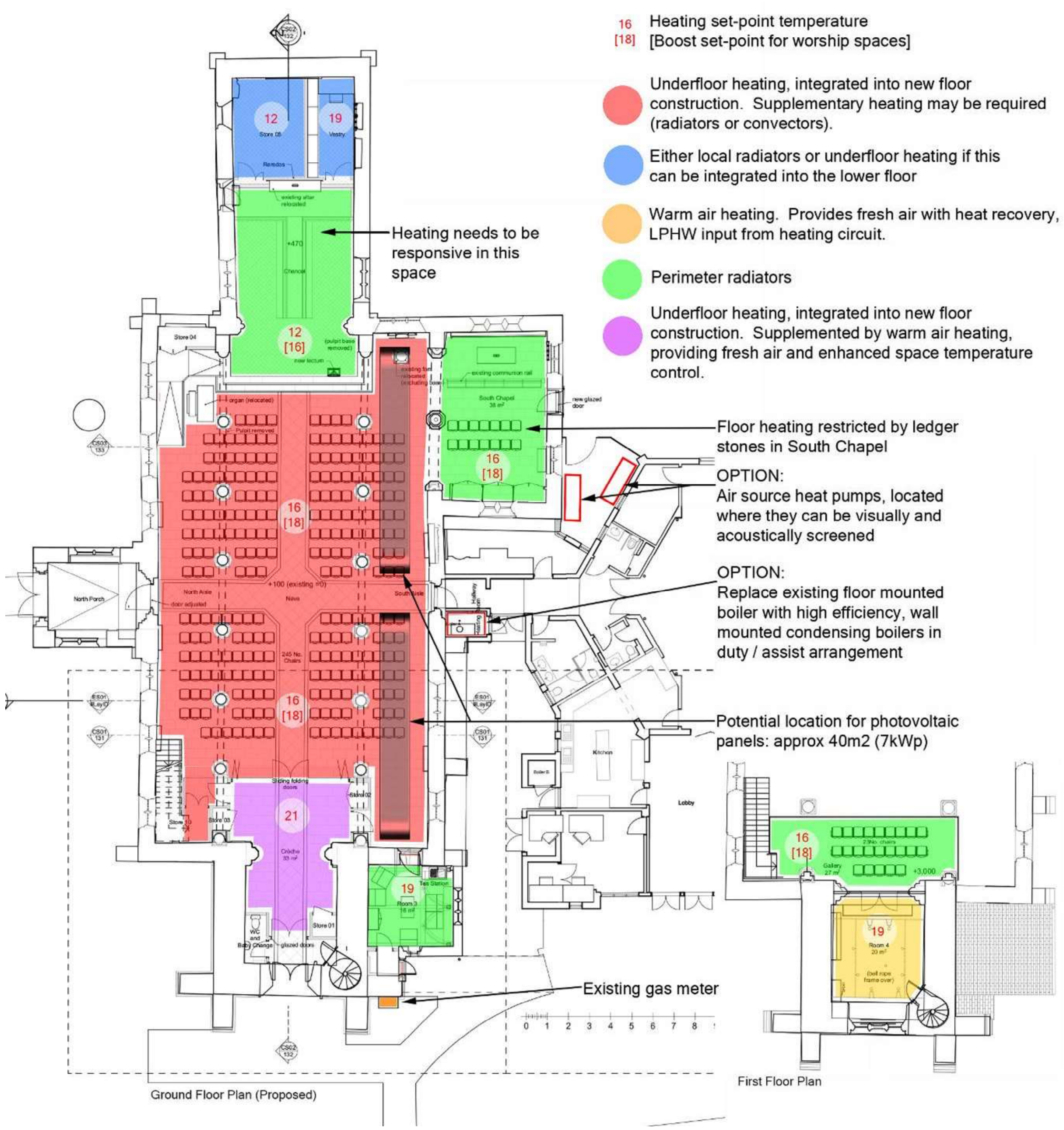
Incorporating photovoltaic panels on the south aisle roof (7.4kWp array over 40m^2 of available roof) will increase the capital premium to £57,000. The value of electricity offset (without any incentives or export value) is predicted to recover the investment within 22 years.

Sensitivity assessments with variations in comparative future escalation rates for gas and electricity, and operating efficiencies for the heat pumps do not alter these returns on investment significantly.

On a financial level, the air source heat pump option should not be considered as an investment that will return the capital within any reasonable period. Consideration should, however, be given to potential carbon emissions reductions – particularly in light of the recent Church of England commitment to achieve net-zero emissions from its buildings by 2030.

An air source heat pump, in comparison to gas boilers, could achieve a 67% reduction in CO_2 emissions. Incorporating photovoltaic panels could improve this to 74% reduction.

The carbon intensity of grid electricity has reduced significantly over recent years, and assuming a sustained reduction over the life of the system (leading to a largely decarbonised electricity network by 2050), an air source heat pump solution could achieve up to 90% reduction in carbon emissions.



1 St Mary's Church

St Mary's, in the Diocese of Ely, is a grade 1 listed church originating from the 13th century and adapted up to the 19th century with extended nave clerestory and chancel roof, steeple and vestry. The principle elements have been assessed for their thermal properties to develop a heat loss model for the church:

- Solid stone walls with internal Victorian plaster. The 'U' Value for this has been estimated at $1.9W/m^2K$ (*CIBSE Guide A*).
- Timber framed roofs with interior panelling. Without any information to the contrary it should be assumed these are entirely uninsulated, with an estimated 'U' value of $2.3W/m^2K$ (*CIBSE Guide A*).
- Solid floor of variable construction - mostly quarry tiles with areas of concrete infill. The fixed pews are on elevated timber platforms. The 'U' value for this has been assessed using perimeter methods (from CIBSE Guide A) at $0.49W/m^2K$. This method works on the basis that heat loss is primarily occurring at the perimeter, with the bulk of the floor in contact with an earth mass at a higher, constant temperature. For the purposes of estimating losses from the church, improvements to the floor have been included which improve the 'U' Value to $0.3W/m^2K$.
- Glazing has been estimated to have a 'U' value of $5.75W/m^2K$.

Using CIBSE methods, a peak design heat loss for the church has been estimated to be 78kW at an outside temperature of -3°C.

This is an appropriate figure on which to establish plant sizes against, although it is necessary to factor in local weather data and a realistic expectation of building occupancy to estimate annual energy demands. The methods behind this are explained later in this report.

2 Transformation Proposals

The following descriptions are based on ArchAngel drawing 0406-111.1 GF and FF Plan.

2.1 Building Proposals

The transformation proposals include a number of building fabric interventions to create new accommodation within the worship space and bell tower:

- Formation of a mezzanine gallery; creating an extended enclosed space below the bell tower for a creche (including baby change and WC), and an enclosed meeting space in the ringing chamber above. Separation of the creche from the worship space is provided by a glazed partition.
- Transformation of the main worship space; replacement of the fixed bench pews with flexible seating.
- Transformation of the chancel to create a more flexible space for services, including relocation of the altar and reredos to provide storage and a new vestry, and removal of the pulpit to provide band space around a more modern lectern. The new store and vestry are partitioned but have no ceilings.
- Conversion of the existing vestry into a meeting room.

The above proposals necessitate modifications to and levelling of the existing floors.

The transformation proposals do not extend into the adjacent community hall, although there is a desire to create a more open entrance which may involve reducing the size of the existing boiler room which is housed in the link corridor.

2.2 Outline Heating Proposals

Primary distribution of heating pipework will be through the existing network of floor trenches. These will be adapted within the flooring works to create service routes for pipes and cables linking each area of the church. The method of heating for each area is detailed on drawing 19-ALA05 M800 (appended to this report) and summarised below:

Nave and Aisles: with substantial reflooring works planned within the main worship space, underfloor heating pipework will be incorporated into the new floor make-up. This will be configured in 8 zones and served from 2 manifolds located in store cupboards. The underfloor heating alone will not provide enough heat input to meet peak heat losses (around 19kW input against 40kW peak loss), although it will be sufficient to maintain both constant, low impact background heating as well as good comfort conditions for congregations and visitors for most of the year. Supplementary heating is deemed to be required to meet peak losses; improve responsiveness and to counter the risk of downdrafts occurring from the windows. Floor trenches will be integrated into the new floor along the North and South Aisles to incorporate heating elements.

Gallery: this area will benefit from residual heat from the main worship space, although additional, vertical radiators will be necessary to maintain comfort conditions and these will be located on the West wall to the rear of the seating area.

South Chapel: flooring works are limited in this area due to ledger stones. Radiators will be incorporated into decorative boxings on the East wall (there is currently a rear panel to a pew against this wall. Discrete, fan assisted convector heaters will be incorporated into storage joinery against the West wall to provide boost heating.

Chancel: radiators located on the North and South walls, with zoned pipework extending into radiators in the new Store and Vestry.

Creche: as an enclosed area this needs managed fresh air as well as relatively high comfort temperatures. Underfloor heating will be extended into this area, across 2 zones and served from a manifold located in the store cupboard. Supplementary heating and conditioning of fresh air into the room will be through a fan coil unit concealed within the gallery floor structure. This will take air from the main volume within the worship space, elevate the temperature and distribute it throughout the Creche.

Meeting Rooms: served by radiators. The Bell room has a very high ceiling and it will be necessary to provide some supplementary heating from a wall mounted fan convector.

2.3 Heating Control, Zoning and Operation

There is no desire to incorporate complex controls for the heating. The new system will incorporate weather compensation and optimisation controls to work automatically in response to external conditions. Control of each space will be as follows:

Underfloor heating systems set on simple time-schedules and air temperature controls. These will be set to maintain a constant set-back temperature outside of occupied hours, and while occupied each manifold will regulate to maintain constant floor temperatures. Regulation of floor temperatures will be zonal to allow the system to self-regulate for local solar gains.

Radiator circuits to each zone will be set to provide boost heat during occupied hours, with weather compensation and optimisation in addition to internal air temperature sensors for each zone. Radiators will also be equipped with thermostatic valves to regulate against localised temperatures.

Fan coil units will be controlled locally and on demand. This will provide immediate boost heat to the local area (eg; to pre-warm the South Chapel, or to lift air temperatures before the Creche is occupied) but allow local over-ride if noise needs to be reduced (expectations should be that even with quiet, modern fan coil units, they will get noisier over time).

3 Heating and Energy Options

3.1 Brief Options Appraisal

Various options for heating plant are described in previous reports, and include:

- Gas fired boilers – practically a replacement of the existing boiler plant.
- Air source heat pumps, located in a screened compound outside the building.

A number of options are discounted in these reports, including:

- Electrical radiant heaters: unlikely to provide sufficient heat or comfort for the various zones, and will almost certainly require supplementary heating. An upgrade to the electrical supply will also be necessary.
- Electrical panel and storage heating: storage heaters can exploit variable tariffs to charge 'off-peak' although in a space such as this they would be difficult to control effectively. They would require supplementary heating and an upgrade to the electricity supply.
- Direct, gas fired warm air systems: visually intrusive and would require substantial builderswork as each heater would require a flue directly to outside.
- Ground source heat pumps: compromised by the restricted land around the church (assuming much of it will be subject to prohibitive archaeological and heritage constraints and will require detailed Faculty oversight) and limited space to accommodate the heat pump plant.

From observations of the building and assessments of the heating needs, we would concur with the above assessment and recommend either replacement gas boilers or air source heat pumps.

3.2 Gas Boilers

A basic assessment of building heat losses suggests a total heating demand of 80kW (around 160W/m^2), although for much of the year the heating demand will be significantly less and an appropriate boiler arrangement would either be a single unit (as per the existing arrangement) with a modular burner – or two boiler modules providing duty and assist. Either arrangement will offer efficient heat generation at variable demands, but providing two or more boiler modules offers a number of practical benefits:

- Boilers can be wall mounted and equipped with pre-fabricated circulation and gas train connections; making better use of the existing boiler room space.
- Having two independent boilers gives resilience. If one boiler fails, heat can be still be generated, albeit at a lower output.

The existing boiler (Ideal Concord C330) has a rated output of 97kW. On this basis, there is no reason to assume any capacity issues on the incoming gas supply, although replacement boilers may require a different regulated pressure and some adjustments at the meter may need to be considered.

A gas boiler solution would be equally suited to radiator and underfloor heating systems, although energy benefits can arise through underfloor heating as this makes condensing boilers more effective.

Condensing boilers recover heat that would otherwise be wasted through the flue gases and under certain conditions this recovered heat can improve the boiler efficiency by up to 10%. These conditions relate primarily to the operating temperature of the system and the lower water temperatures required by underfloor heating systems mean that return temperatures can be managed to ensure the boilers operate in 'fully condensing' mode for longer periods of time.

No additional plant space will be required to accommodate replacement gas boilers, although the existing boiler room will need to stay at its current size and this option will limit opportunities to alter or enhance the side entrance to the community hall.

3.3 Air Source Heat Pumps

Air sourceheat pumps use a refrigerant vapour compression cycle to extract heat from the air and transfer it into a heating medium -typically water. The compression cycle is driven by electricity and the heat pump efficiency is measured in terms of useful heat extracted per unit of electricity used. This 'coefficient of performance', or CoP is typically between 250% and 450%, meaning for each kWh of electricity used, between 2.5 and 4.5kWh of heat can be extracted. This makes heat pumps comparable in running costs with high efficiency gas boilers, and with recent adjustments to the carbon factors between natural gas and grid electricity, they can provide significant carbon emission savings.

The CoP is governed by the temperature 'lift' or difference between the system supply temperature and the outside air. This means that although heat pumps can commonly extract useful heat out of air as low as -20^{o}C, they will do so with a much reduced efficiency. However, when coupled with a low temperature heating system such as underfloor heating, an air source heat pump system can operate at peak efficiency for long periods of time.

Air source heat pumps are a relatively new solution for churches. Although a number of case studies are offered up in the Church of England Shinking the Footprint initiative, relatively few completed and operating systems exist.

Attitudes towards ASHP solutions for church heating have generally been mixed; partly due to unrealistic performance promises or sold solutions that do not adequately anticipate the use of the church. It is important that any technical solutions are based on conservative efficiency standards. This ensures savings are achievable and performance is guaranteed all year round.

Expectations are also commonly held that heat pumps are a niche technology which requires specialist and expensive maintenance. It is true that ASHP plant will demand a rigorous planned maintenance regime to ensure the full life of the plant can be enjoyed with optimum efficiency, although in terms of maintaining warranties on the plant, and mandatory safety requirements, similar maintenance plans should be put in place for gas boilers. The practical difference between the two is often down to who is

Heating Options and Outline Services Proposals

St Mary's Church, Ely

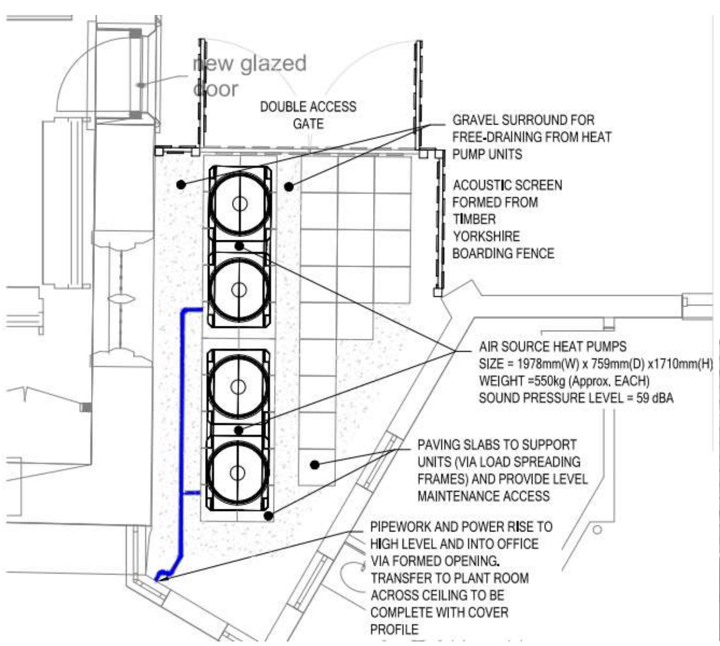
19-ALA05

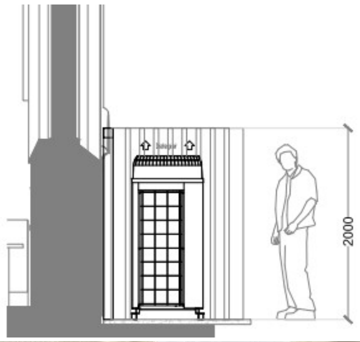
able to maintain the plant. Heat pump manufacturers often require accredited and certified engineers, whereas boiler manufacturers only require engineers who are trained to work on their products.

According to the *Building Services Component Life Manual* (published by the Building Performance Group) which gives guidance on expected 'useful economic life-spans' for plant and equipment, the life spans for gas boilers and air source heat pumps are comparable – between 15 and 20 years. Economic useful life is not a prediction of failure. It is a prediction of a number of factors relating to the cost effective maintenance of plant and equipment; such as availability of spares, frequency of failure. The expected life for a heat pump system is generally predicated on a large number of moving components (fan bearings, compressors), although these are generally replaced or refurbished as part of ongoing routine maintenance. On this basis, risk of catastrophic, irreparable failure (which for gas boilers would be a rupture of heat exchangers or deterioration of the 'back end' due to corrosive flue condensate) would be lower, more predictable and easier to address.

Two key practical constraints need to be overcome before air source heat pumps can be considered appropriate for a church setting:

- Space – larger, commercial units can require a significant footprint to maintain airflow, maintenance access and safe discharge of condensate. At St Mary's, there is a recess located between the South Chapel and the Community Hall where units can be located with little visual impact.





- Noise – during normal operation, the heat pump units are relatively quiet although during periods of high demand noise can increase. Noise issues can also arise during defrost cycles where the units operate to clear ice forming on the external coils. Demands can be managed during the day when ambient noise is less problematic; although defrost cycles can occur at any time. A detailed noise assessment will need to be carried out on any system design, and a degree of acoustic screening will be required. Unless neighbours are very close to the units, screening can often take the form of simple hit-and-miss fencing, with much of the attenuation occurring over distance.

The electricity supply will also require upgrading. This is currently a single phase supply from a three-phase service cable in the bell tower. It is possible that an upgrade will require only the other two phases to be energised with a replacement meter; although a formal application will be necessary to establish this. For viability purposes it is assumed a replacement service will be required.

3.4 Photovoltaic Solar Panels

The roof to the South Aisle is south facing, concealed from normal views and recently re-clad with concrete tiles. All of these factors are conducive to incorporating solar panels in a non-obtrusive and non-invasive manner.

Using hooks that wrap around the tiles; a discrete support frame can be integrated into the roof with only minor fixings into the timbers beneath.

An initial assessment (this will need to be verified by a more thorough study for structural integrity and overshading) suggests a panel array of 40m^2 can be accommodated. This would provide a system rated at around 7.4kWp with the potential to yield 5,370kWh of electricity each year.

A detailed assessment of the roof structure would need to be undertaken to ensure the additional weight of solar panels and supports can be accommodated.

Financial incentives for solar panels are currently uncertain. The Feed-in-Tariff scheme which paid an index linked unit subsidy for renewable electricity stopped taking applications in April 2019. A replacement scheme which pays a tariff for renewable electricity exported into the grid – termed the Smart Export Guarantee – is currently in consultation. It is likely that such a scheme will require a specific export tariff arrangement with eligible suppliers, and will definitely require a smart meter.

For the purposes of viability, solar photovoltaics are assessed on their capital cost against the value of electricity offset. This assumes all of the electricity generated is used and on this basis such a scheme would complement the air source heat pump option.

4 Systems Comparisons and Viability

It should be noted that the cost estimates given below are based on only a preliminary assessment of heat losses and heating demands.

Capital costs use tender return data from other, similar projects, although they are applied to very sketchy design information.

Energy use data is based on a year of local degree day data applied to a preliminary heat loss estimate, although the heat loss and patterns of use are based on judgments rather than established data.

On this basis, the data given in this section should be considered only in terms of comparisons (orders of magnitude sufficient to inform a value judgment) rather than predictions. Further design work will be necessary to refine these for the benefit of project cost plans and risk assessments.

4.1 Radiators -v- Underfloor Heating

For the purposes of establishing principles for a developing design; radiators should be deemed to include all types of passive heating emitters – including concealed heaters in fixtures or plinths.

Radiators should incorporate a number of characteristics that will limit the available ranges and manufacturers, and inevitably increase the price compared to traditional steel panel radiators. The cost premium for these characteristics should be viewed in terms of value for the benefits gained:

- Separate heat exchanger: meaning the panel enclosure is separated and has a lower contact temperature. This is important when locating radiators close to seating areas or in parts of the church where community gatherings are anticipated.
- Low water volume: reducing the total weight of the radiator, and ancillary plant requirements as system expansion is lower.

The cost comparison given below is based on radiators meeting the above criteria.

Radiators can also be incorporated into joinery items, fixed furniture, ramps, etc. This comparison assumes a similar out-turn cost.

For the purposes of comparison, the underfloor heating option is assumed to extend only to the areas of floor being adapted and levelled, with space to avoid or accommodate ledger stones. An allowance for supplementary heating in the form of panel radiators or heaters integrated into joinery items has been made.

Both options include an allowance for air heating to the creche and meeting rooms. This will be in the form of a ventilation unit, incorporating heat recovery and a controlled heating connection.

An outline budget should be anticipated for a radiator system at around £29,000. To incorporate underfloor heating into the adapted areas of floor and supplement this with fewer radiators, a budget of £34,500 should be anticipated: a £5,500 premium. This cost premium provides the following benefits:

- Less visible and physical intrusion into the worship space. Radiators will almost certainly impact on the transformation proposals to create adequate wall space to accommodate them and this may have cost impacts in other areas of the project.
- Lower risk of leaks in the worship space. Workmanship and materials specifications can be enhanced to mitigate these, but pipework joints and fittings cannot be entirely avoided and each one presents a risk of failure. Underfloor heating pipework is continuous with joints only located at manifolds.
- More even and efficiently distributed heat. A warmer floor improves comfort throughout the congregation and increases the mean radiant temperature of the space – meaning a marginally lower output from the heating system.

4.2 Boilers -v- Air Source Heat Pumps

Replacement boilers will necessitate a complete refit of the current boiler room. An allowance has been made to replace the flue, although without any significant builderswork requirements as the roof penetration and weathering already exist.

A budget of £50,000 should be anticipated to provide two wall mounted condensing gas boilers with primary circulation plant (pumps, expansion and controls) and gas service alterations.

Builderswork requirements for air source heat pumps are reasonably simple: a level hardstanding to support the units and gravelled surrounds to allow condensate and rain water to discharge safely in cold weather. The existing boiler room will be re-purposed to accommodate buffer vessels and internal distribution plant and can be reduced in size accordingly. Allowances for building alterations and acoustic screening have not been included.

A budget of £97,200 should be anticipated for two monobloc air-to-water heat pumps, located externally and connected to internal primary distribution plant. This includes an allowance to upgrade the electrical supply to the church.

The budget cost premium for air source heat pumps is £47,200. This comes with cost-in-use benefits which are described below. It also comes with significant savings in carbon emissions. From preliminary assessments this saving could be as much as 13.4tonnes per year. Assuming an economically useful life of 20 years, an air source heat pump solution could save around 268tonnes of CO_2 compared to gas boilers.

4.3 Solar Photovoltaic Panels

A budget of £10,000 should be provisioned for the installation of a 40m^2 panel array on the South Aisle roof.

The cost benefits of this are summarised below – but only in terms of the electricity consumption offset. This budget does not allow for any battery storage. The primary demands for the church are during sunlight hours and any electricity generated would be used by normal activities – particularly when used in conjunction with an air source heat pump. Future government incentive schemes are likely to place a value on excess electricity exported to the grid. Both of these factors make battery storage largely unnecessary.

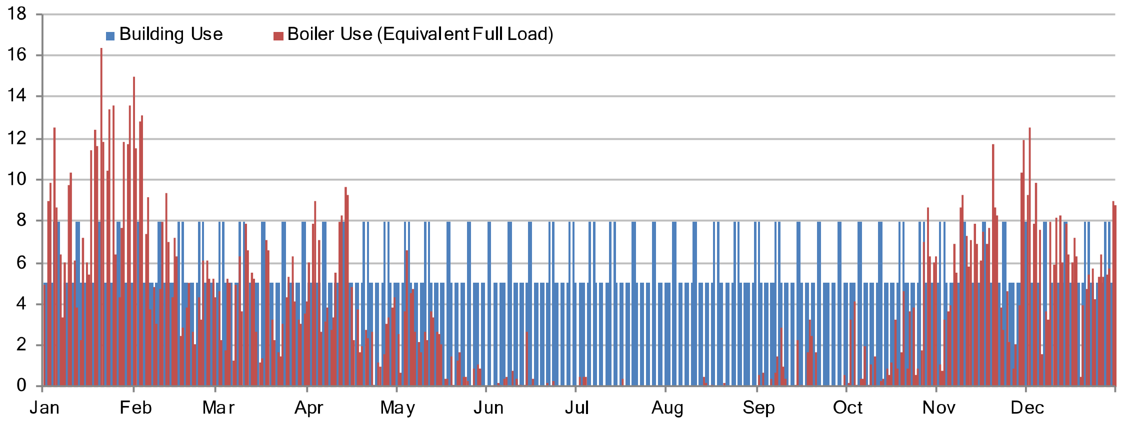
A 40m^2, 7.4kWp array would save in the region of 1.4tonnes of CO_2 per year; 27tonnes over a 20 year life span.

4.4 Heating Energy Demand Assessment

For both options, an assessment of the building heating loads (using CIBSE heat loss methods) has been carried out, and used alongside degree day data from the Cambridge Weather Station (period 01 January 2019 to 31 December 2019).

Degree day data is an indication of a regional need for heating based on recorded temperatures and an internal 'baseline' temperature – set to anticipate a degree of natural self-heating within the building. For a church the baseline temperature should be quite low – indicating both a lower internal set-point temperature (an average of 16°C based on zonal set-points) and a relatively high degree of self-heating from a heavy thermal mass.

Applying degree day data to the required plant capacities results in a daily estimation of heating operation – and predicted energy demands. This is illustrated below with hours of boiler operation set against a daily occupancy pattern (typically 5 hours occupied during the week; 8 hours during the weekend, and unoccupied hours at a set-back temperature).



As a sense check, the energy demand predictions were compared against gas demands for the period 15 November 2018 to 15 May 2019. The predictions are within 5% of known consumption data, so although this method should not be considered accurate by any usual standards, for the purposes of comparing likely energy demands from heating options it is appropriate.

4.5 Cost In Use Assessment

The following comparisons are for the total life costs (initial capital + annual energy costs over a 25 year span) for the following systems:

- Gas boilers: £50,000 initial capital budget
- Air Source Heat Pumps: £97,200 initial capital budget
- Air Source Heat Pumps coupled with Solar Photovoltaics: £107,000 initial capital budget

System life is taken at 25 years for all options – this being a period beyond typical product warranties, and with expectations of increasing maintenance burden, but where wholesale replacement of plant is not expected and the system performance is maintained through routine maintenance.

Costs are adjusted for present value, using a nominal discount factor of 2.5%.

Energy costs are assumed to escalate by an average of 5% each year.

Both of the above factors are fairly arbitrary, although they are useful in establishing a comparison that anticipates rising fuel costs and can be judged in terms of today's value of capital.

Gas costs are set at 4.5p/kWh

Electricity costs are set at 12p/kWh

There are sensitivities around future fuel costs that are driven by immediate and short-term factors (fuel price caps, geo-political events) as well as more sustained influences over longer terms (decarbonisation of the UK energy infrastructure, established government policy, mix in power generation plant, take-up of new technologies such as renewables and electric vehicles). Predictions of fuel cost escalation, even over short-terms, vary but a number of common themes suggest a reasonable degree of parity between gas and electricity (sources: *National Grid Future Energy Scenarios 2019*):

- Financial disincentives away from gas will reduce the consumer market demand (by as much as 60% over the next 25 years), although it will remain a significant source for electricity generation for much of this period and in this regard largely drive the cost of electricity.
- Increases in gas costs will likely be matched by an increased cost of decarbonising the electricity network.

Energy costs for the air source heat pump assume an average CoP of 3. The proposed unit (Mitsubishi CAHV) has three published efficiency (CoP) levels based on external air and required system temperatures:

Air at 7°C, system flow temperature at 45°C: 3.49 [heating season average- full load]

Air at 7°C, system flow temperature at 35°C: 4.13 [heating season average – part load]

Air at -3°C, system flow temperature at 55°C: 2.8 [heating season peak – full load]

These are industry standard figures intended to allow comparisons between systems under the same conditions. They do, however, represent a reasonable estimate of operating conditions [indicated above in brackets], and with outside temperatures typically averaging around 7°C during the heating season, and the system design 'peak' demand occurring at an external temperature of -3°C, an assessment based on an average CoP of 3 should be considered to be conservative.

The graph (over) illustrates the lifetime costs of these options, showing that the additional investment in air source heat pumps are not likely to be returned within 25 years (<4% ROI), and the additional investment in photovoltaics will improve this to 22 years (4.5% ROI).

A sensitivity assessment on fuel escalation suggests that in order to achieve a 7% return on investment (payback within 15 years), the cost of gas would have to escalate at an annual rate of 6% more than electricity. For the reasons described earlier, this should be considered unlikely.

A sensitivity assessment on the operating efficiency of heat pumps suggests that an average CoP of 3.5 would improve the return on investment to 5% (payback within 20 years) – or 5.6% (payback within 18 years) if combined with photovoltaics.

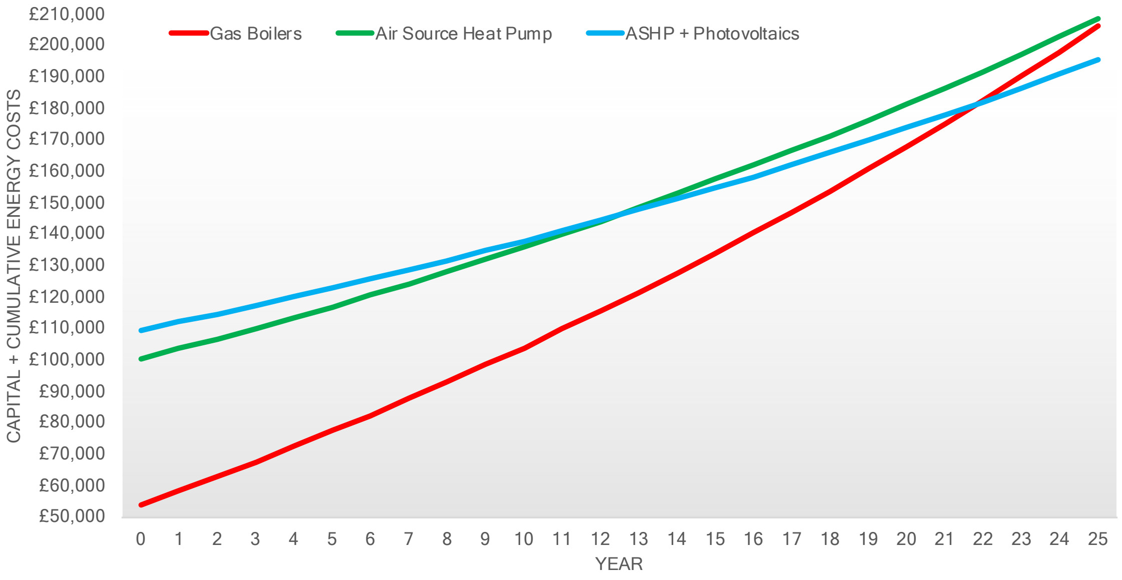
These sensitivity assessments are useful but only demonstrate that marginal influences on both fuel costs and the operating efficiency of the air source heat pumps will not bring the commercial viability of this option within reasonable parameters.

Heating Options and Outline Services Proposals

St Mary's Church, Ely

19-ALA05

The practical conclusion to this viability study is that the additional capital investment in both air source heat pumps and photovoltaic panels are likely to be recovered within the life of the systems, but will provide no reasonable financial return on the investment.

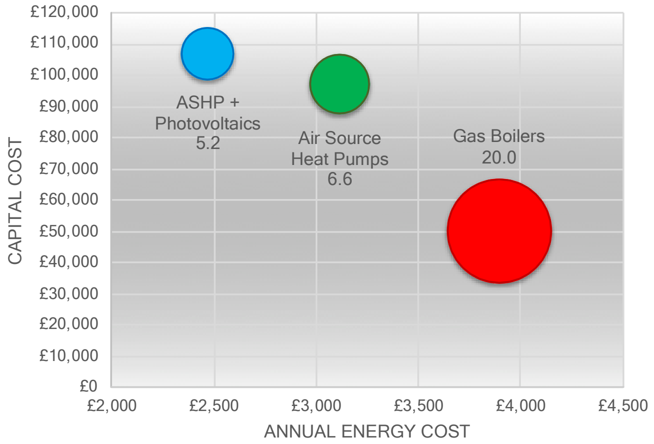


Acknowledging the previously described caveats to this assessment, these estimates are intended to demonstrate achievable ROI targets. A number of factors can also be applied which may improve these assessments significantly:

- Incentives, such as the Smart Export Guarantee will place a value on exported electricity from the solar panels. This may also be a vehicle through which schemes are incentivised through lower tariffs although none of this is currently known and therefore not allowed for.
- The Renewable Heat Incentive (RHI) scheme may be applicable to the air source heat pump; offering 2.5p/kWh (January 2019 tariffs) and significantly reducing the energy costs and payback period for this option. RHI payments are mandated on certain criteria for the building and a more thorough assessment will be required to determine eligibility. On this basis, the tariff benefits have not been included.
- Emerging government energy policy is turning against fossil fuel boilers and towards a smarter, decarbonised electricity grid. Policy intent is demonstrated by the recent commitment to ban gas boilers in new homes by 2025. Although this in itself is not a reason to discount a boiler solution now, such a policy is likely to be balanced with incentives to move towards efficient electrical heating – which may reduce electricity tariffs compared to gas and affect lifetime costs.
- The decision in February by the Church of England Synod to reach 'net-zero' emissions across its building stock (including churches) by 2030 will have a profound effect on attitudes towards renewables technologies. It will also possibly encourage more centralised incentives to invest in renewables. 2030 is less than 10 years into the life of the systems being reviewed in this report.

4.6 Carbon Emissions

Consideration should be given to the carbon impacts of each option. The graph (right) illustrates the relative annual carbon emissions (using current carbon intensities for electricity and gas) for each option in context with the capital budget and predicted annual costs.



An air source heat pump solution could reduce the carbon emissions arising from heating the church from 20 tonnes CO_2 per year to 6.6 tonnes (67% reduction).

Incorporating photovoltaic panels could reduce this further to 5.2 tonnes CO_2 (74% reduction)

These are significant savings, which can also be considered in terms of carbon emissions per £1,000 of capital budget – giving an indication of relative environmental value of each option:

Gas boilers:	399kgCO_2
Air Source Heat Pumps:	67.6kgCO_2
ASHP + Photovoltaics:	48.7kgCO_2

The carbon intensity of electricity (a government metric aggregating the amount of CO_2 emitted per kWh of electricity generated within the UK) has reduced significantly over recent years, with a 50% reduction between 2013 and 2017 (*National Grid Future Energy Scenarios 2018*). If this trend continues towards a decarbonised electricity network (net-zero carbon by 2050: a simplification here as this refers to the decentralised use and generation of electricity as well as the centralised production of energy), the gap in carbon emissions between gas boilers and air source heat pumps could increase to 420 tonnes CO2 over the life of the systems (25 years) – representing an 85% to 90% reduction in total emissions.

5 Electrical Systems Proposals

In addition to the heating options and proposals, the transformation scope will also include upgrades to other key services.

A summary description of these upgrades is given in the following sections. They are also illustrated on drawings:

Power, Containment and Audio Visual Systems:	19-ALA05-E200
Internal Lighting:	19-ALA05-E400

These drawings are appended to this report.

5.1 Lighting

The main design challenges with regard to lighting the interior of the church are:

- Expressing the Nave ceiling and maintaining a good balance of illumination over the main worship space.
- Illuminating the South Chapel – this being a common area for worship and services.
- The physical alterations to the Chancel – requiring flexibility for its use as a stage while also illuminating the altar and reredos.
- Feature lighting to specific plaques and features within the church – keeping in balance with the ambient lighting.
- Avoiding onerous maintenance and cleaning burden in locating new light fittings.

It is also important to avoid unnecessary physical impacts to the church fabric in locating, mounting and servicing new light fittings. A key design aim is to re-use as much of the existing wireways and locations as possible.

The proposals, illustrated on drawing 19-ALA05-E400, essentially replace the existing LED floodlights within the Nave with bracket mounted LED spotlights. Additional LED wash-lights will be fitted to provide an even illumination to the Nave ceiling. All of these will be wired using the existing galvanised metal conduit.

The LED spotlights will also be located along the North and South Aisles and South Chapel; replacing the pendant fittings. New containment will be routed at high level along each aisle to serve both lighting and audio-visual systems.

The spotlights within the South Chapel will supplement the existing decorative pendants. These will be taken down; rewired and fitted with new LED lamps.

The Chancel is currently illuminated with high level floodlights and strip lights mounted on the sides of the arch. The floodlights will be replaced with LED spotlights; concealed from view within the roof timbers. The strip lights will be replaced by a flexible track system: this will initially be fitted with additional spotlights to make an illuminated backdrop of the altar and reredos, but will accommodate an wide range of lights to provide flexibility in future.

Emergency lighting will be required to some of the enclosed and high risk areas (Creche; Chancel); and this will be in the form of miniature LED luminaires which can be discretely located behind timbers and columns. Emergency lighting is less important in the main worship space as this is most commonly used during daylight hours (or while there is sufficient natural light to escape safely) - although these needs will be assessed in further detail. Consideration will also be given to a small static inverter unit - which can be located centrally and provide a backup supply to selected general light fittings in the event of a power failure – removing the need to locate additional emergency fittings within the worship space. The costs and practical impacts of this option will be reviewed during the next stage of design.

Lighting controls will be incorporated to allow graduated lighting levels – both to save energy and also to integrate with audio-visual systems.

5.2 Power

The need for power within the church is driven by two primary uses:

- Audio visual systems – both direct power to the audio-visual equipment, and general power for flexible use of the space for services and performances.
- Community use of the worship space.

The provision of new power should balance these needs with requirements for public safety and preservation of the building fabric and a strategic rather than a blanket approach should be adopted in allocating new power points.

The locations indicated on the drawings will require careful review to ensure they meet the specific needs for each room and space.

Primary containment for new power will be incorporated into the new floor. This provides a degree of future flexibility and also minimises the visible surface containment – with low level sockets wired through short lengths of conduit emanating from the floor rather than from high level.

The demand for power within the new reordered church will be dictated mainly by the heating option. If gas boilers are retained, the current 100Amp rated single phase supply is considered sufficient to meet the needs for lighting and power.

If a heat pump system is adopted – or photovoltaic panels are incorporated, the incoming supply will require an upgrade to three phases. This may physically only involve energising the current cables and replacing the building meter. Enquiries are currently out with UK Power Networks to establish the costs and impacts of upgrading.

5.3 Audio Visual Systems

The church is currently equipped with cabling, sound and lighting equipment. The intention of this scope is to incorporate (and tidy up) current arrangements – and facilitate future flexibility (or incorporate any new equipment, systems or cabling requirements as they are communicated to us).

To this end, the scope will include:

- Space and power connections to accommodate a central audio rack. This will collect all of the audio cabling connections to band equipment and stage mics from new floor boxes into a central point. This also allows stage lighting controls to be incorporated.
- New audio and network links to potential stage management desk locations. Initially these will be taken to the current desk location, but the developing design will take advice from the Church's sound teams to decide on the best location and arrangement. The provision of cabling and containment will assume a replacement and simplified control desk arrangement.

- Containment routes incorporated within the new floor construction to serve the current audio-visual systems and provide future flexibility for new systems. These will be supplemented by new high-level routes along each aisle to serve high level speakers, screens, projectors, etc.
- Replacement main audio speakers – locations indicated, although the speakers and equipment will be selected by the Church.
- Replacement organ speakers. Assuming replacements can be sourced that will replicate the required tone and sound quality from the organ. Specialist input will be required for this.

5.4 Fire, Safety and Security Systems

The widening of use and occupancy for the church, particularly with community spaces such as the creche and meeting rooms come with a requirement to enhance fire alarm and detection arrangements.

The proposals will include provision of new, wireless detection devices to cover areas of high risk and enclosed spaces. These include the Chancel (fire risk associated with electrical, audio and visual equipment), creche and meeting rooms.

The main worship space will require only limited coverage and the proposals will anticipate a need to enhance detection and provide alarms to compensate for additional escape distances from the upper gallery.

The requirements for fire detection and alarms will be developed in detail with input from the Building Control and Fire Officers for the transformation project.

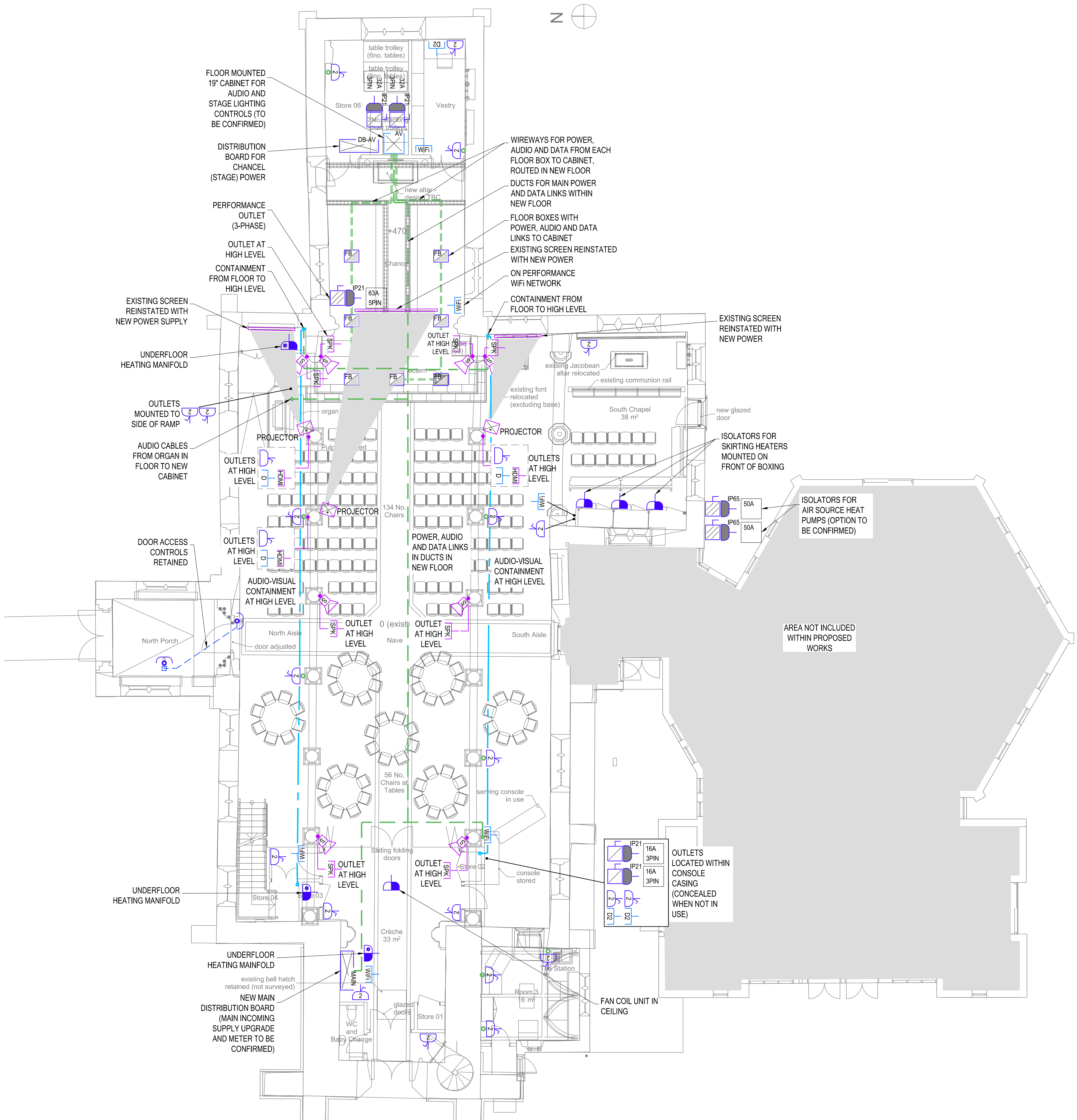
It is not anticipated that any enhanced security provisions will be necessary, although if required these can be incorporated using wireless systems with minimal physical impacts on the building fabric. In this regard, such systems will be explored and developed during the forthcoming design periods.

Appendix A

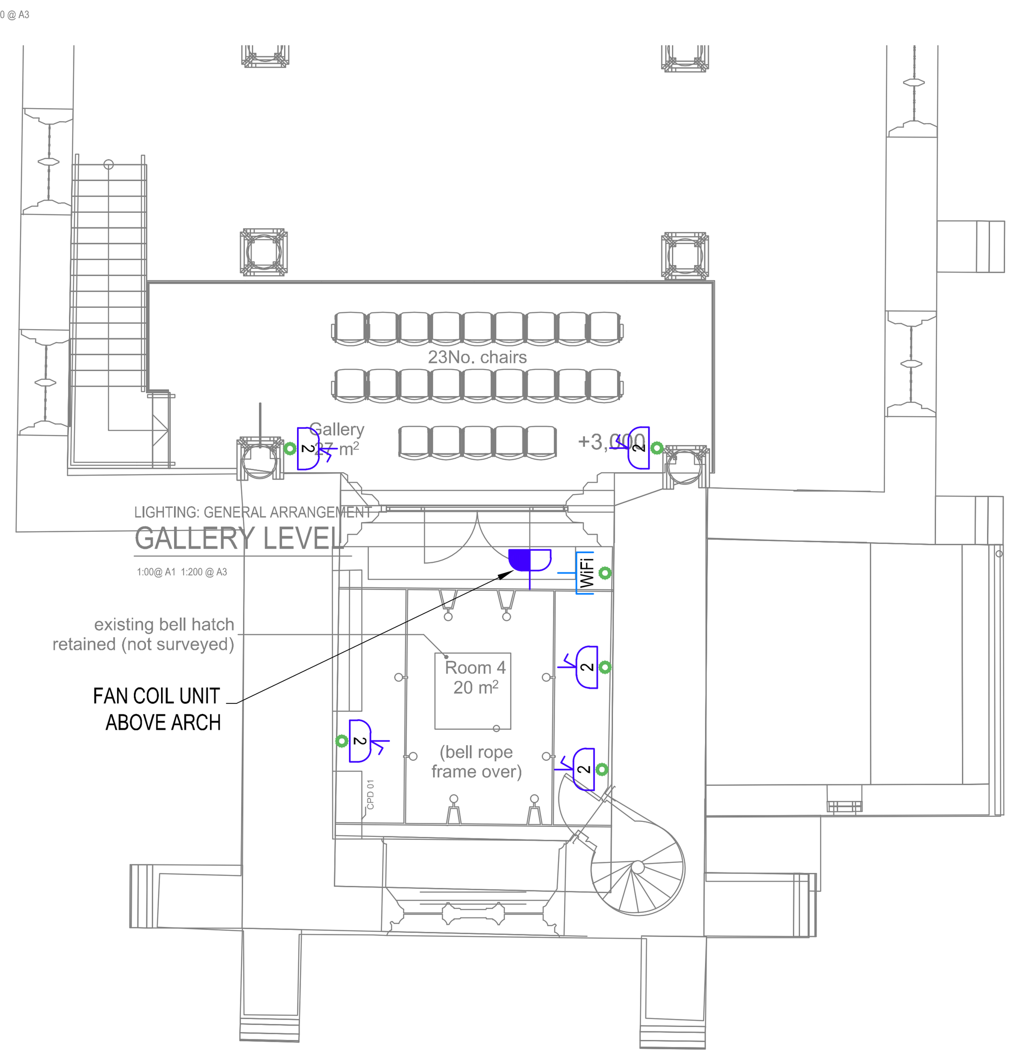
Proposal Drawings

Preliminary Issue

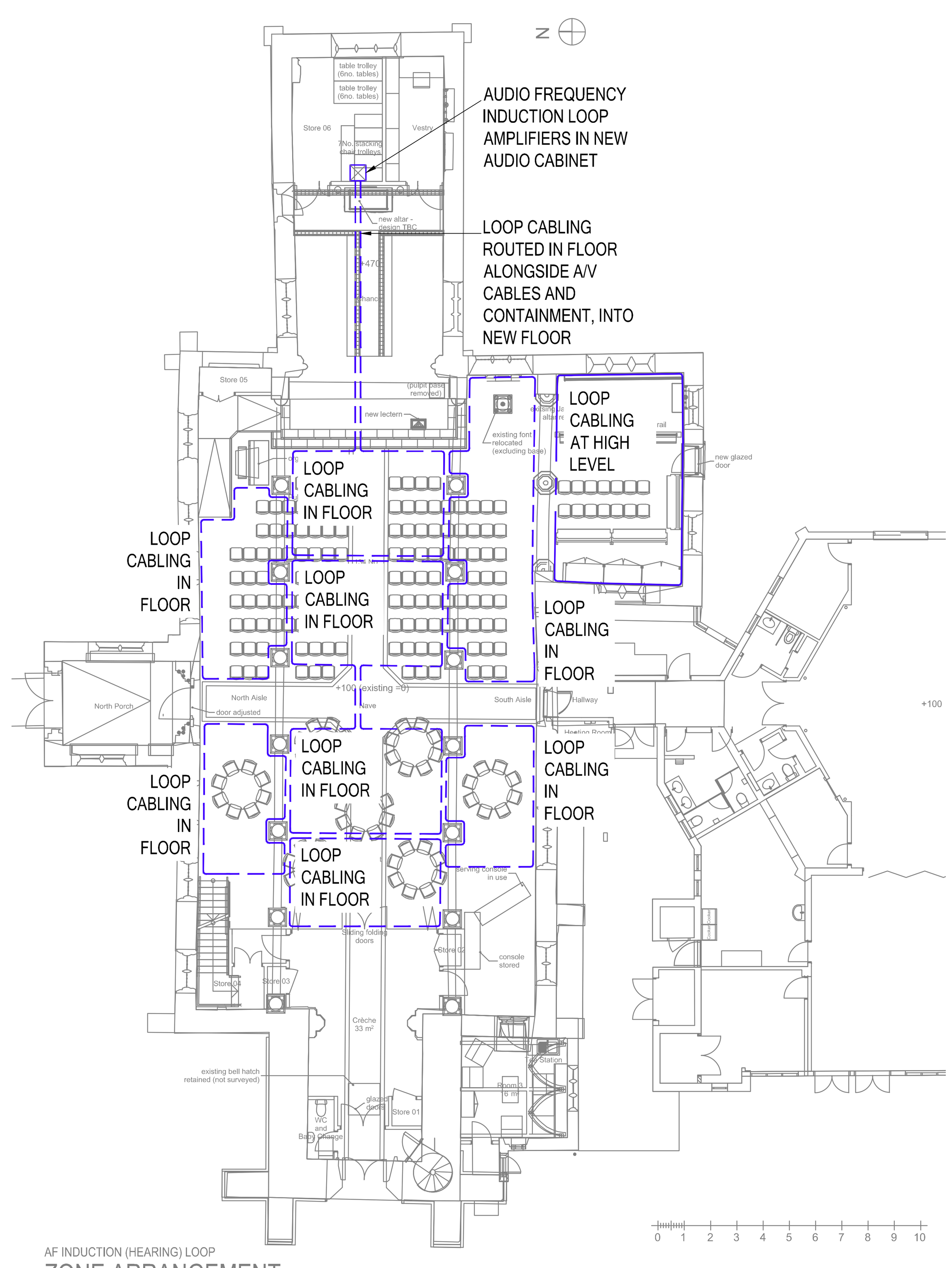
19-ALA05-E200:	Power and Containment Proposed Arrangement
19-ALA05-E400:	Internal Lighting Proposed Arrangement
19-ALA05-M800:	Heating Proposed Arrangement



POWER AND CONTAINMENT
GROUND FLOOR
1:100@A1 1:200@A3



POWER AND CONTAINMENT
GALLERY LEVEL
1:100@A1 1:200@A3



AF INDUCTION (HEARING) LOOP
ZONE ARRANGEMENT
1:200@A1 1:400@A3

Key Plan

Base Layout
Arch Angel

Notes

Revision	Date	Description	Drawn	Checked
P1	09.03.20	PRELIMINARY ISSUE FOR REVIEW	SJ	MB

BUILDING SERVICES CONSULTING ENGINEERS
Eco Innovation Centre, Peterscourt,
City Road, Peterborough, PE1 1SA,
t: 01733 308234,
w: www.illuminousconsult.com.

Client
ST MARY'S ELY

Project
St Mary's Church, Ely
Transformation Project

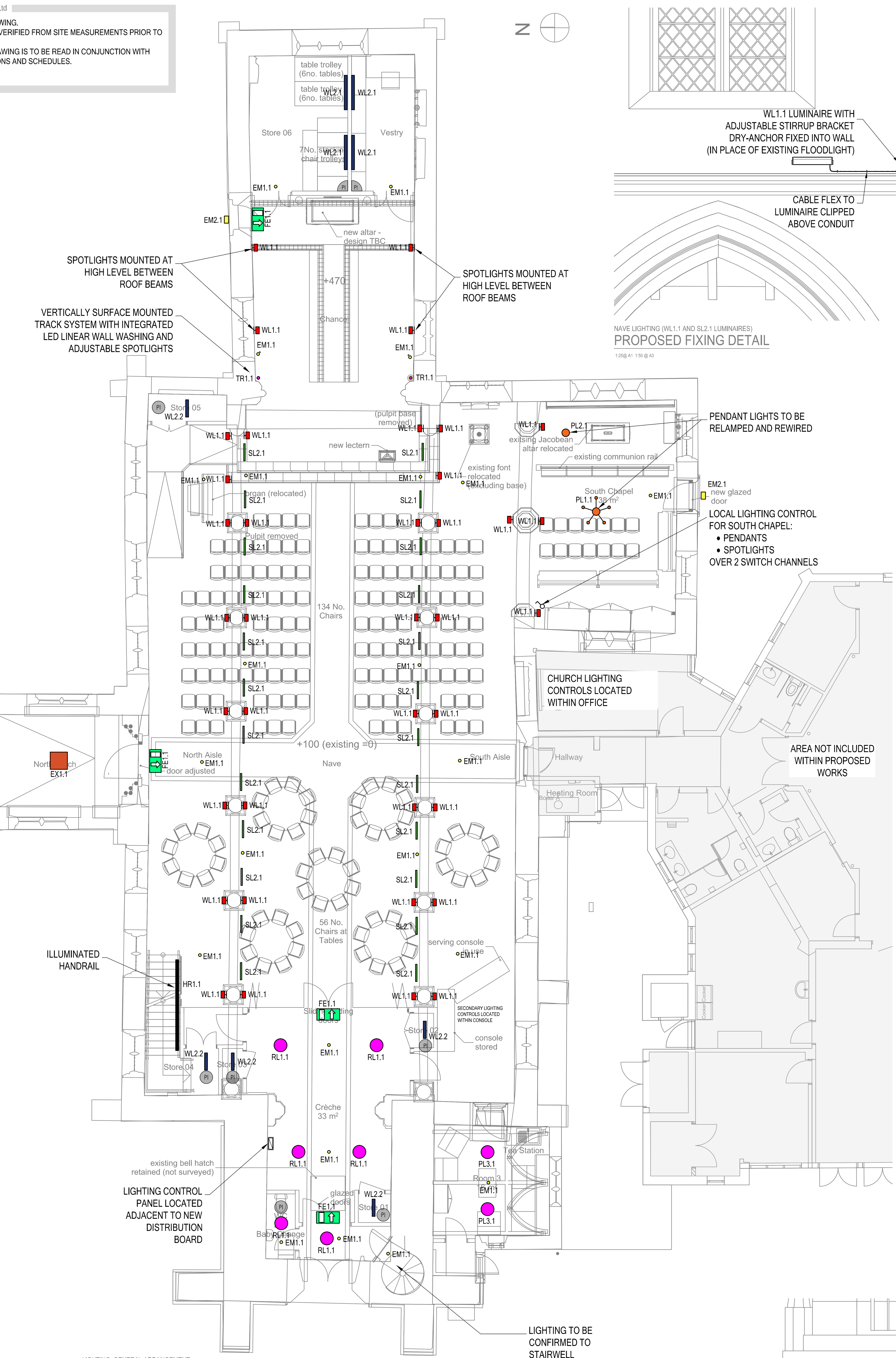
Drawing Title
Power and Containment
Proposed Arrangement

Status	Drawn	Checked
Preliminary	SJ	MB

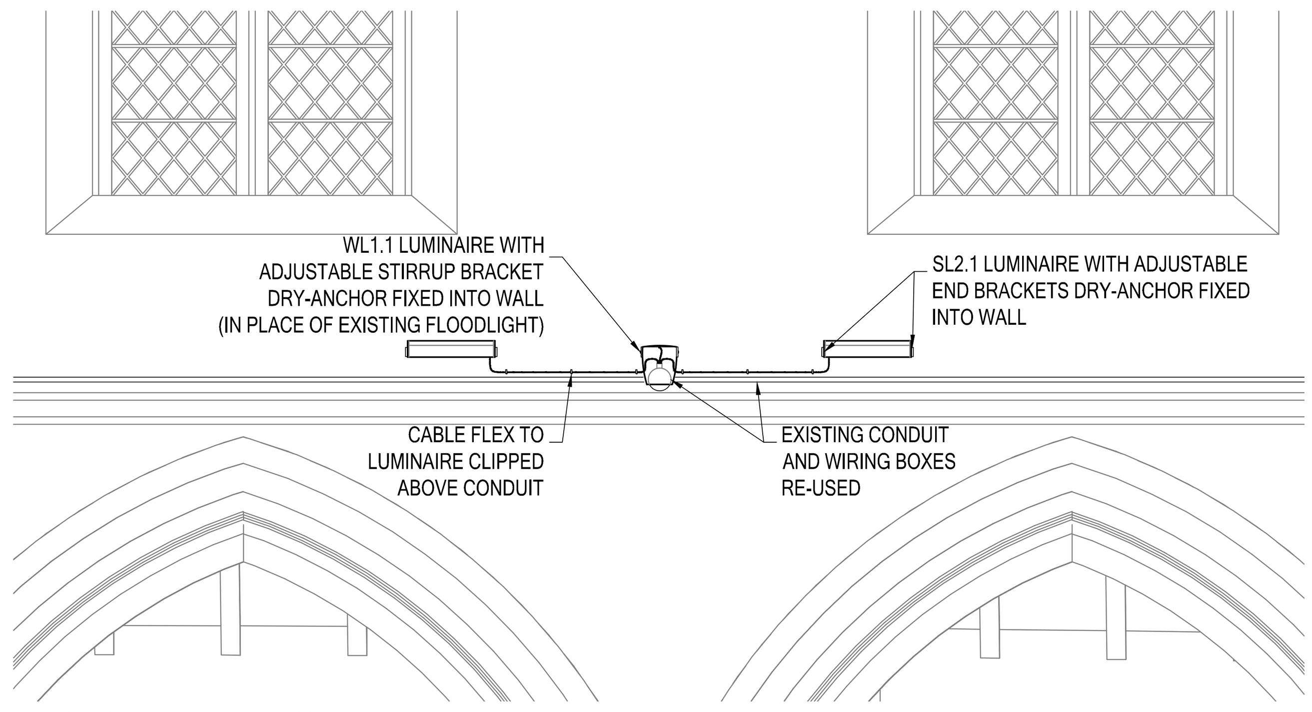
Project Ref	Drawing	Revision
19-ALA05	E200	P1

Scale	Date
As Shown	Jan 20

DO NOT SCALE FROM THIS DRAWING.
GIVEN DIMENSIONS ARE TO BE VERIFIED FROM SITE MEASUREMENTS PRIOR TO COMMENCEMENT OF WORKS.
THE INFORMATION ON THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE ASSOCIATED SPECIFICATIONS AND SCHEDULES.



LIGHTING: GENERAL ARRANGEMENT
GROUND FLOOR
1:100@ A1 1:200 @ A3

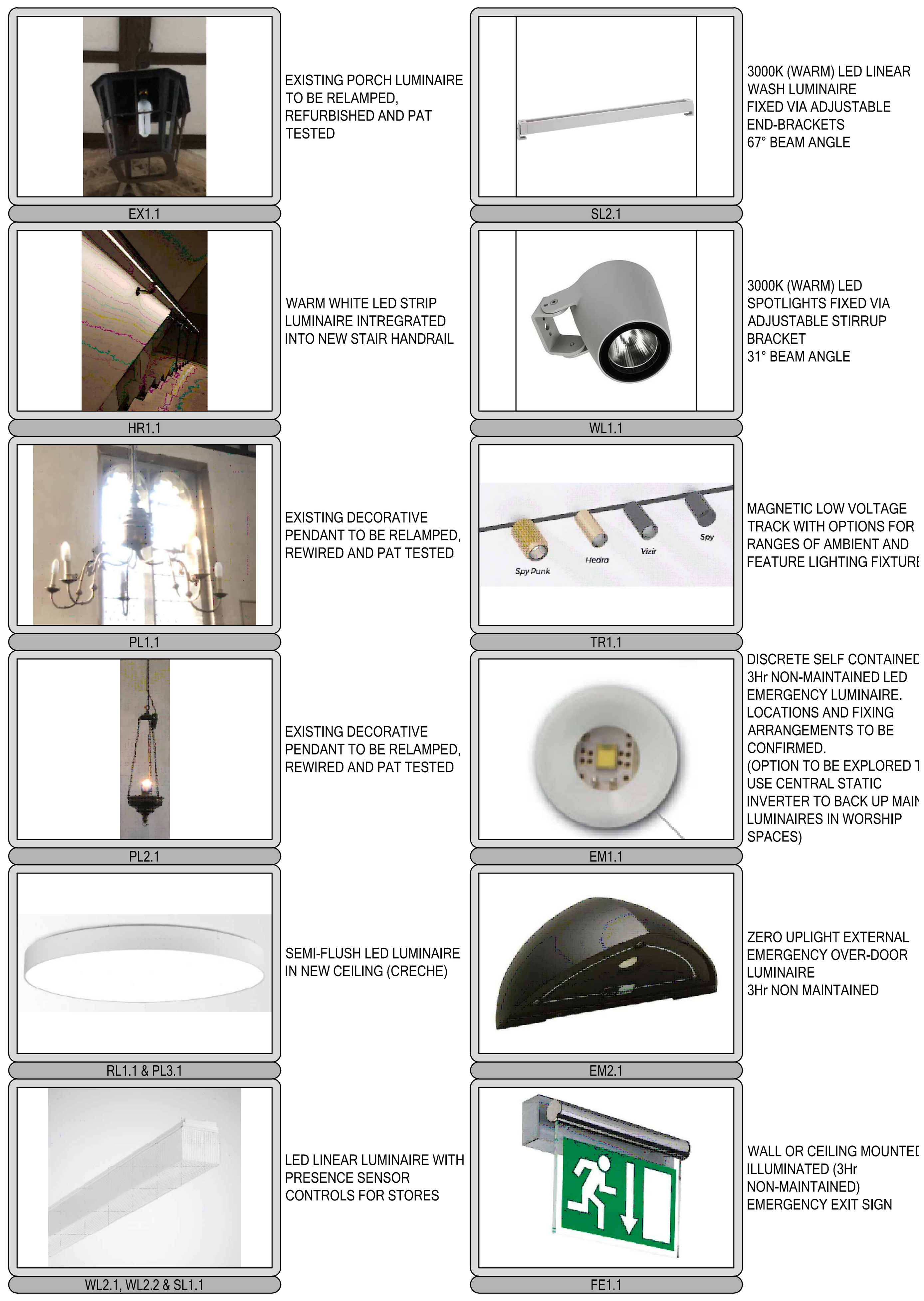


NAVE LIGHTING (WL1.1 AND SL2.1 LUMINAIRES)
PROPOSED FIXING DETAIL
1:10@ A1 1:20 @ A3

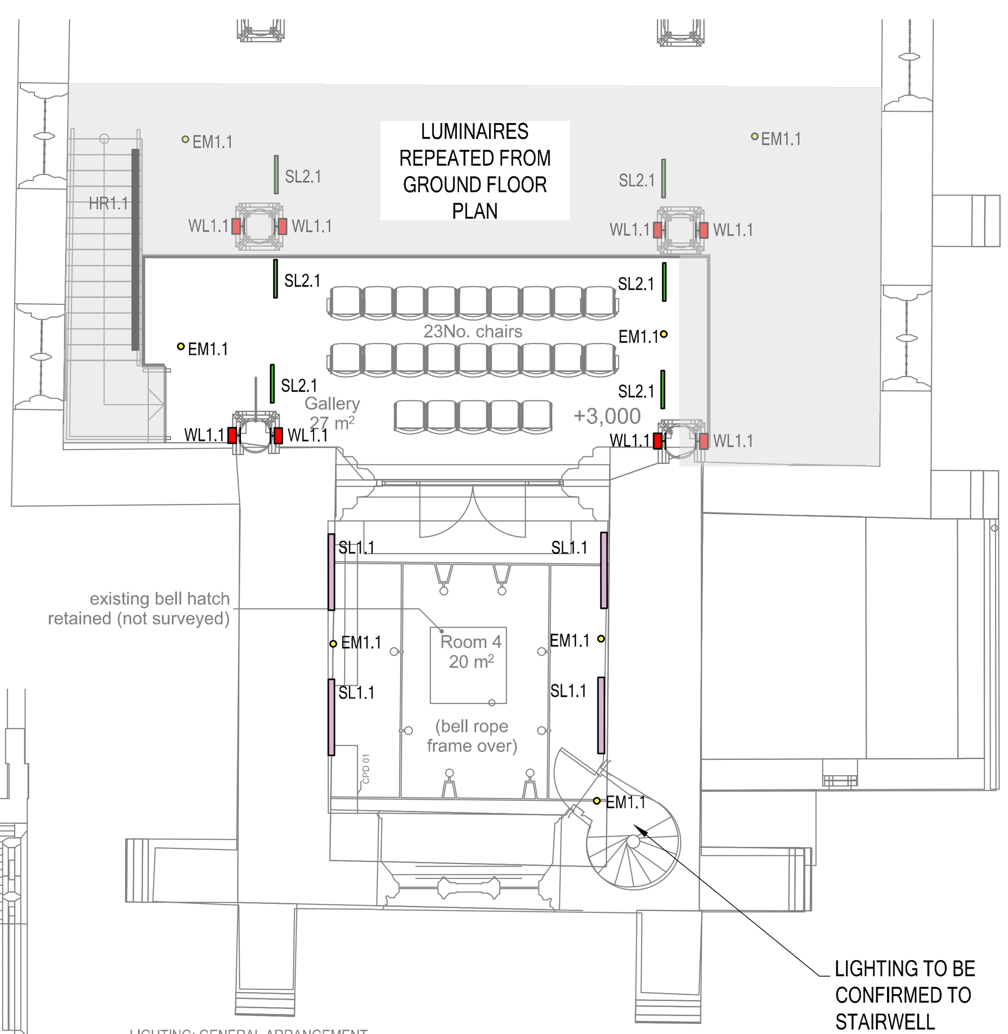
Key Plan

Base Layout
Arch Angel

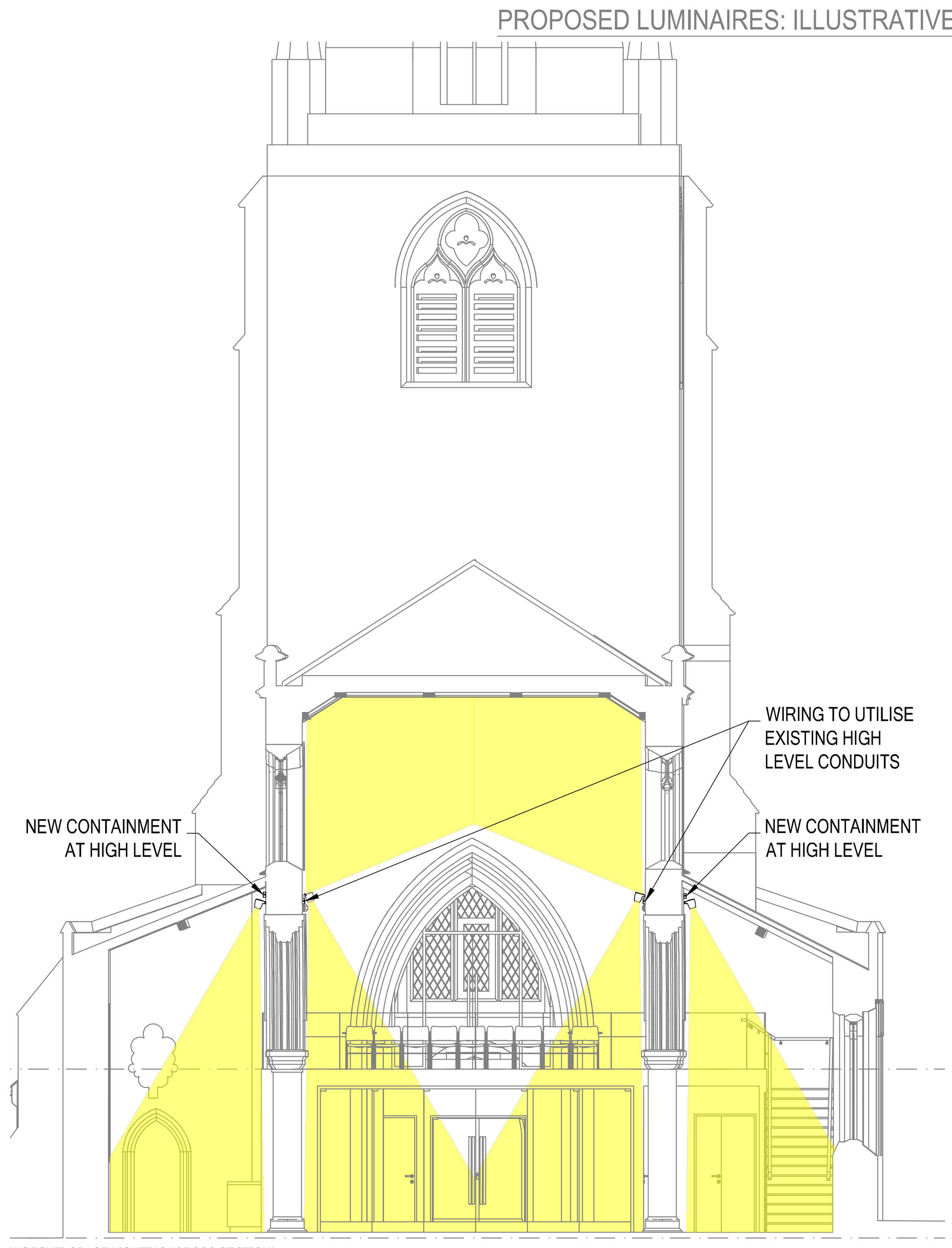
Notes



PROPOSED LUMINAIRES: ILLUSTRATIVE KEY



LIGHTING: GENERAL ARRANGEMENT
GALLERY LEVEL
1:100@ A1 1:200 @ A3

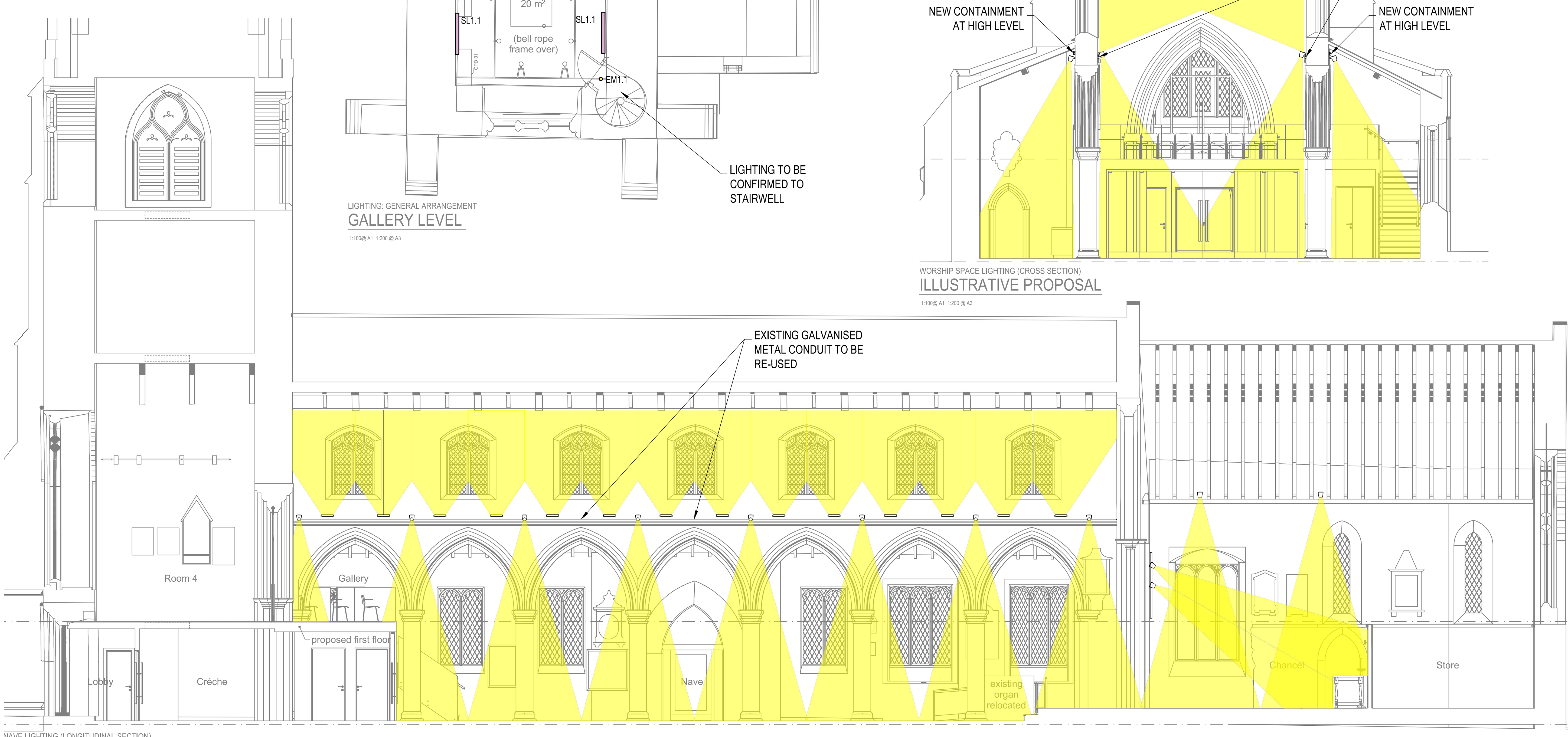


WORSHIP SPACE LIGHTING (CROSS SECTION)
ILLUSTRATIVE PROPOSAL
1:100@ A1 1:200 @ A3

LIGHTING CONTROL CHANNELS					
CHANNEL	ZONE	CONTROL			
		SCENE 1	SCENE 2	SCENE 3	SCENE 4
1	NAVE SPOTLIGHTS	OFF	OFF	ON	ON
2	NAVE UPLIGHTS	ON	ON	ON	ON
3	CHANCEL SPOTLIGHTS	OFF	OFF	ON	ON
4	CHANCEL TRACK LIGHTS	ON	ON	ON	ON
5	NORTH AISLE	OFF	ON	ON	ON
6	SOUTH AISLE	OFF	ON	ON	ON
7	FONT SPOTLIGHT	ON	OFF	OFF	ON
8	ORGAN SPOTLIGHT	ON	OFF	OFF	ON
9	SOUTH CHAPEL	ON WITH SCENES 1-4, LOCAL OVER-RIDE CONTROL			
10	CRECHE	LOCAL PRESENCE AND SWITCH CONTROLS			
11	STORE / VESTRY	LOCAL PRESENCE AND SWITCH CONTROLS			
12	NORTH PORCH	TIME-SCHEDULE WITH DAYLIGHT SENSING			

DIMMING ARRANGEMENTS TO BE CONFIRMED ALONGSIDE FINAL LUMINAIRE SELECTIONS

LIGHTING CONTROLS
PROPOSED SCHEDULE



NAVE LIGHTING (LONGITUDINAL SECTION)
ILLUSTRATIVE PROPOSAL
1:100@ A1 1:200 @ A3
0 1 2 3 4 5 6 7 8 9 10

Revision	Date	Description	Drawn	Checked
P1	09.03.20	PRELIMINARY ISSUE FOR REVIEW	SJ	MB

illuminous

BUILDING SERVICES CONSULTING ENGINEERS
Eco Innovation Centre, Peterscourt,
City Road, Peterborough, PE1 1SA,
t: 01733 308234,
w: www.illuminousconsult.com.

Client
ST MARY'S ELY

Project
St Mary's Church, Ely
Transformation Project

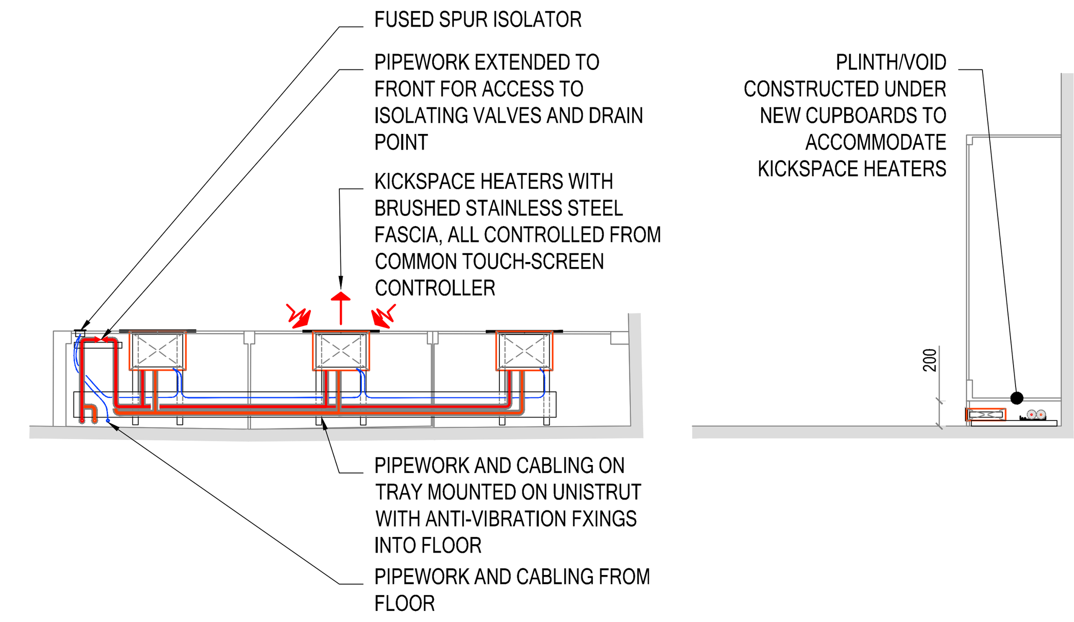
Drawing Title
Internal Lighting Proposed Arrangement

	Drawn	Checked
Preliminary	SJ	MB

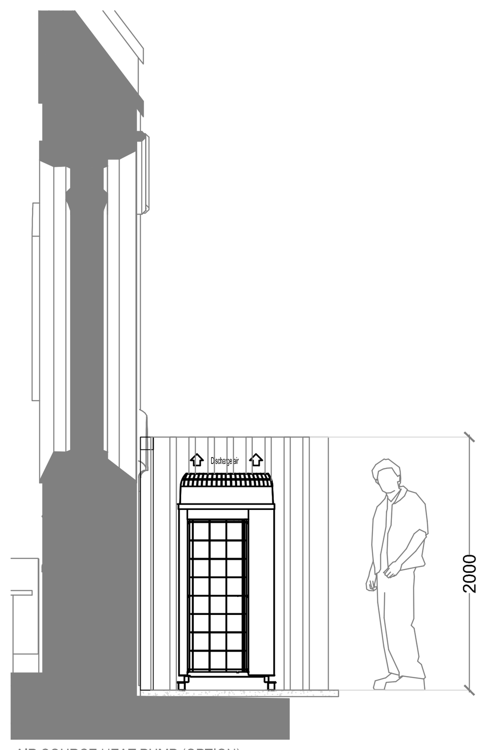
Project Ref	Drawing	Revision
19-ALA05	E400	P1

Scale	Date
As Shown	Jan 20

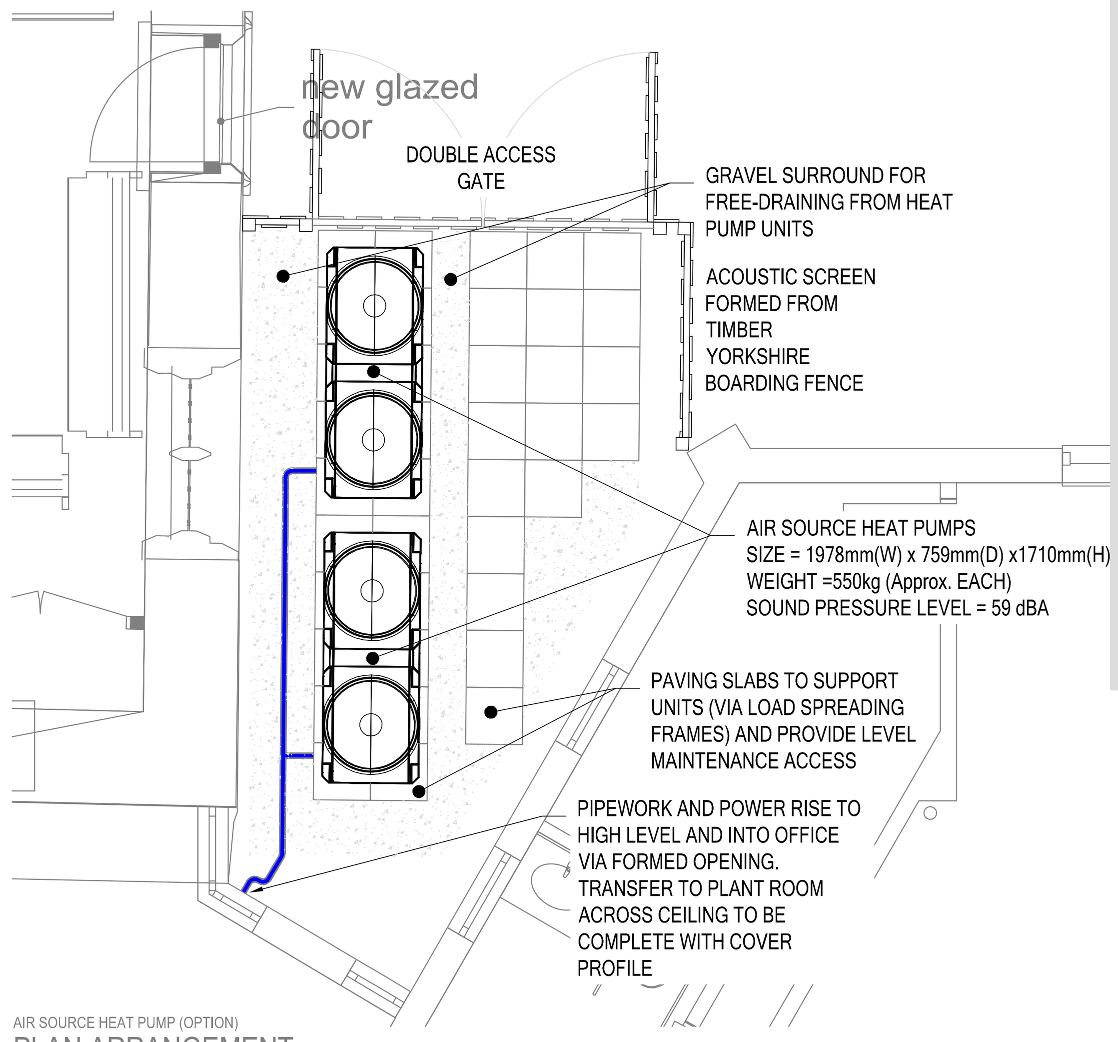
DO NOT SCALE FROM THIS DRAWING.
GIVEN DIMENSIONS ARE TO BE VERIFIED FROM SITE MEASUREMENTS PRIOR TO COMMENCEMENT OF WORKS.
THE INFORMATION ON THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE ASSOCIATED SPECIFICATIONS AND SCHEDULES.



SOUTH CHAPEL KICK-SPACE HEATERS
INSTALLATION DETAIL



AIR SOURCE HEAT PUMP (OPTION)
SECTION ARRANGEMENT



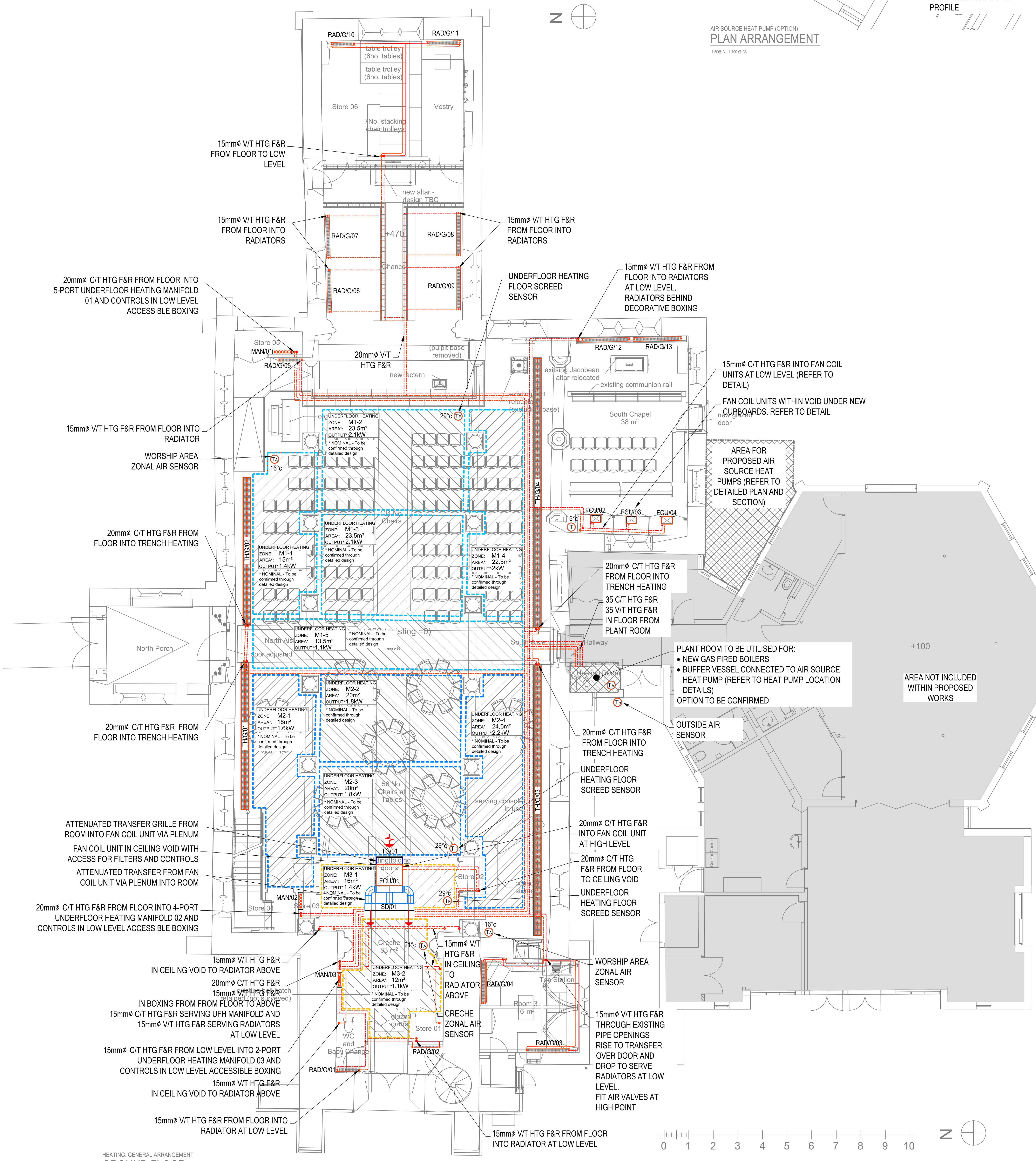
AIR SOURCE HEAT PUMP (OPTION)
PLAN ARRANGEMENT

Key Plan

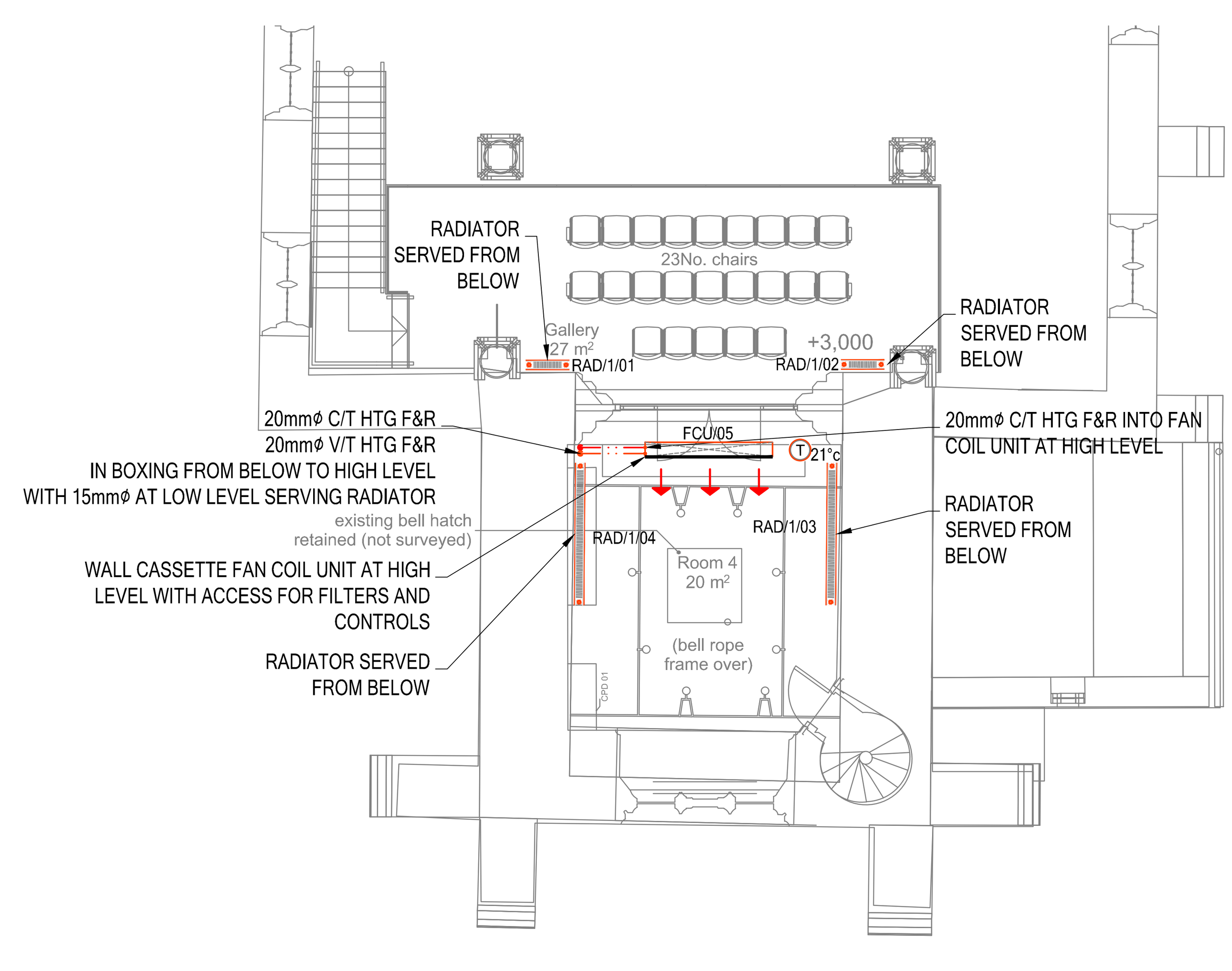
Base Layout
Arch Angel

Notes

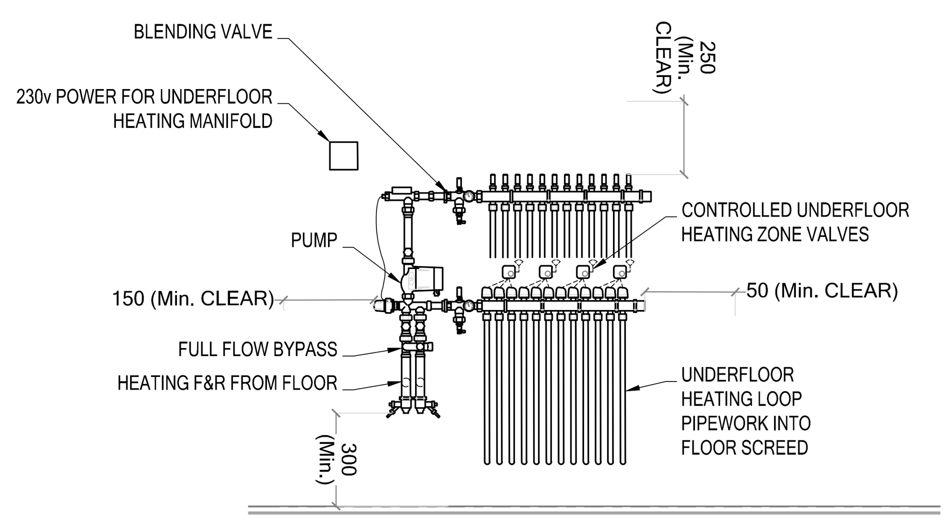
1. THIS DRAWING IS NOT TO BE SCALED.
2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE RELEVANT CONTRACT DOCUMENTATION.
3. DIMENSIONS ARE IN MILLIMETERS UNLESS STATED OTHERWISE.
4. REFER ALSO TO SCHEMATIC DETAILS.
5. ALL PIPEWORK UNLESS STATED OTHERWISE SHALL BE IN PAINTED STEEL WITH MALLEABLE FITTINGS (PAINT COLOUR TO BE CONFIRMED).
6. ALL PENETRATIONS THROUGH FIRE COMPARTMENTS SHALL BE FULLY SEALED WITH FIRE COLLARS AS REQUIRED.
7. DRAIN POINTS SHALL BE FITTED AT THE LOWEST POINTS OF THE SYSTEM AND AUTOMATIC AIR VENTS AT THE HIGHEST POINTS OF THE SYSTEM AND INDICATED ON THE INSTALLATION DRAWINGS.
8. UNLESS SPECIFIC REQUIREMENTS ARE INDICATED, EXPANSION AND CONTRACTION SHALL BE ASSESSED BY THE CONTRACTOR AND INDICATED ON THE INSTALLATION DRAWINGS. WHERE POSSIBLE MOVEMENT SHALL BE TAKEN UP BY CHANGES IN PIPE DIRECTION.
9. ALL PIPEWORK BRANCHES SHALL BE COMPLETE WITH ISOLATION / COMMISSIONING VALVES IN FULLY ACCESSIBLE LOCATIONS.
10. ALL ROOM THERMOSTAT LOCATIONS SHALL BE AGREED PRIOR TO THEIR FINAL FIXING.
11. ALL CONTROLLER LOCATIONS SHALL BE AGREED PRIOR TO THEIR FINAL FIXING.
12. UNDERFLOOR HEATING TO BE INSTALLED BY MANUFACTURER APPROVED INSTALLER.



HEATING: GENERAL ARRANGEMENT
GROUND FLOOR



HEATING: GENERAL ARRANGEMENT
FIRST FLOOR



UNDERFLOOR HEATING
MANIFOLD DETAIL
Not To Scale

Revision	Date	Description	Drawn	Checked
P1	09.03.20	PRELIMINARY ISSUE FOR REVIEW	JG	MB

illuminous

BUILDING SERVICES CONSULTING ENGINEERS
Eco Innovation Centre, Peterscourt,
City Road, Peterborough, PE1 1SA,
t: 01733 308234,
w: www.illuminousconsult.com.

Client
ST MARY'S ELY

Project
St Mary's Church, Ely
Transformation Project

Drawing Title
HEATING
PROPOSED ARRANGEMENT

Status	Drawn	Checked
Preliminary	JG	MB

Project Ref	Drawing	Revision
19-ALA05	M800	P1

Scale	Date
As Shown	Jan 20