REPORT

# Temple Gate MSCP Life Care Plan

*Prepared for*

# Bristol City Council


April 2018

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# Acronyms and Abbreviations

| | |
|---|---|
| RC | Reinforced concrete |
| ICE | The Institution of Civil Engineers |
| LCP | Life Care Plan |
| BCC | Bristol City Council |
| BRE | Building Research Establishment |
| ASTM | American Society for Testing and Materials |
| UKAS | United Kingdom Accreditation Service |
| ASR | Alkali Silica Reaction |
| AAR | Alkali Aggregate Reaction |
| ACM | Asbestos Containing Materials |

SECTION 1

# Executive Summary

## 1.1 Scope

This report details the inspection and assessment of the structure and fabric of Temple Gate MSCP in the centre of Bristol, in accordance with the Institution of Civil Engineers report 'Recommendations for the inspection, maintenance and management of car park structures, 2002'. The works were undertaken cognisant of BCC's aspiration of modernising the car park and implementing a pay on foot (POF) system.

The elements of this work included the following:

- An Initial Appraisal involving a review of archive material to assess in-situ construction details and previous inspection reports;
- Condition Survey and Structural Investigation which included site and laboratory testing of the concrete elements characterise properties and condition;
- Structural Appraisal - an evaluation of the structure via desk study and calculations;
- Recommendations for prioritised remedial actions and maintenance works; and
- Recommended inspections, assessments and maintenance regimes.

This report provides recommendations for the immediate actions (Table 1.1), and sets out further analysis that is required to optimise the future management of, and expenditure on this structure.

The regimes for daily surveillance, routine inspections, special inspections and appraisals, including maintenance and repair guidelines, are set out in Table 8.1 of this report.

## 1.2 Condition Survey and Structural Investigation

The main high and medium priority defects and actions noted were:

- Missing (failed) blockwork along the perimeter elevation, requiring further investigation of the remaining cavity walls and repair of the sections with missing blockwork.
- Inadequate vehicle and pedestrian barriers, requiring replacement to meet modern code requirements.
- Stair/lift tower glazing systems extensively deteriorated and in need of substantial refurbishment and repair.
- Spalling to the concrete deck and soffit, resulting primarily from chloride-induced reinforcement corrosion, and requiring repair and future enhanced protection.

It is noted that the layout of the structure places restrictions on the dimensions available for parking and circulation, which could significantly impact POF operation, and further consideration is required prior to significant works and investment.

## 1.3 Structural Appraisal

Based on limited analysis, it is concluded that there are some areas where the capacity of the frame and decks are not proven to be as large as would be expected. Without further analysis and or investigation works it is not yet clear if the structure is inadequate for the anticipated full design load, or whether insufficient investigation has been undertaken to identify all the reinforcing bars in the beams, columns and slabs.  Further investigation into the columns and slabs is recommended.

# 1.4 List of Actions

A complete list of recommendations is included in Section 8.6.5. High priority works, as identified by BCC in March 2018 are given in Table 1.1. These are based on a pragmatic 'maintain and repair' approach, with a view to attaining a further 10-year service life, described as Option B in Section 8.7.

TABLE 1.1
**Summary of Actions for Maintenance Option B**

| Item | Priority | Maintenance action | Cost (£) |
|---|---|---|---|
| 1 | High | Investigations to determine the stability and condition of the South elevation infill blockwork masonry walls [no allowance for repairs]. Access cost included. | £7,000 |
| 2 | High | Repair of the southwest elevation infill blockwork masonry walls. Access cost included. | £33,000 |
| 3 | High | Install additional handrailing to stairwells | £5,000 |
| 4 | High | Refurbishment of Staircase A glazing system (entrance elevation) | £19,000 |
| 5 | High | Refurbishment of Staircase B glazing system (rear elevation) | £13,000 |
| 6 | High | Perimeter barriers | £189,364 |
| 7 | High | Internal Barriers | £67,574 |
| 8 | High | Refurbishment of Staircase A concrete cladding (entrance elevation) | £12,000 |
| 9 | High | Refurbishment of Staircase B concrete cladding (rear elevation) | £7,000 |
| 10 | High | Deck concrete repairs | £13,392 |
| 11 | High | Soffit & upstand concrete repairs | £9,730 |
| 12 | High | Elevation concrete repairs | £2,575 |
| 13 | Medium | Replacement of roofing material to staircases and lift core roofs | £4,000 |
| | | **Total** | **382,635** |

Notes: BCC denotes the action urgency is to be set by BCC. For 10-year operation, all High priority actions should be implemented.

SECTION 2

# Introduction

## 2.1 Background

CH2M HILL/Jacobs was appointed by Bristol City Council (BCC) to undertake a study to provide the necessary baseline information and determine the maintenance and inspection requirements of the structure and fabric for the Temple Gate MSCP, to allow the development of a Life Care Plan (LCP).

In 2017, there were plans to introduce a pay on foot (POF) system. By March 2018 BCC had decided to introduce 'pay and display' type parking instead of POF. The existing contract parking is to be relocated to the upper decks. The 'pay & display' car park at ground level will remain as such.

A survey of the current condition of the infrastructure was required to help preserve and enhance safety, functionality and future revenue, and identify and address any related health and safety concerns. Of particular concern to BCC is identification of failures of the structure, including spalling, pot holes and any other risks to customers / the general public, and managing the risk of closure due to structural defects. BCC also wishes to introduce additional CCTV, paint the stairwells and have proprietary coatings for the decks, lift lobbies and stairs. The overall purpose of this commission is to assess current condition and identify, specify, and supervise works to be undertaken by others in order to meet BCC's aspirations.

## 2.2 Scope

The scope of the study was in accordance with the guidance detailed in the Institution of Civil Engineers (ICE) publication titled "Recommendations for the inspection, maintenance and management of car park structures", first published in 2002. This is summarised in Section 2.3.

Based on the Initial Appraisal, Condition Survey, Structural Investigation and Structural Appraisal, recommended actions in terms of remedial works, further inspection and assessment have been established to enable the management of the structure in accordance within the ICE Guidelines.

These works were initiated with on-site visual inspection for the Condition Survey and intrusive testing and sampling for the Structural Investigation.

This document presents the necessary information to form a LCP for Temple Gate MSCP.

The scope includes the inspection and proposals for the following items:

- Concrete Condition (Ceilings, ramps, decks, pillars, stairwells, walls)
- Drainage
- Curtain wall glazing (Southern stairwell)
- Crash Barriers
- Entry / Exit layout / visibility (suitability for new POF system)
- Deck Surfaces
- Relocation of secure gate / installation of new gate for top deck
- Removal of existing shutters to each deck
- Hand rails within stairwells
- Lift motor room structure
- Aesthetic upgrade of external elevations

Excluded are:

- Electrics
- Toilets
- Topographic, surface & soffit levels survey

## 2.3 Requirements of the ICE Guidelines

The requirements detailed in the ICE Guidelines clearly sets out the responsibilities of the asset owner/operator in terms of maintaining their structure in a safe and serviceable condition.

The Guidelines set out how this can be achieved in a process called Life-care planning. One of the key aspects of this process is ensuring that the safety and serviceability of the structure is verifiable and that evidence of this action is contained in a specific file relating to that facility.

The Guidelines state that the development of a Life-care Plan is based upon a review of the existing records of previous maintenance and repair works, inspection reports and structural appraisals. It is stated that the plan should identify the need for immediate actions and plan for scheduled actions such as further surveillance, inspection or repair, as necessary to implement the overall plan. In this manner, the risks posed by aging structures can be properly managed and major disruption through un-planned emergency repair works is avoided.

The document also recommends that the Owner/Operator of the asset should appoint an experienced Chartered Engineer to advise on structural safety, inspection and maintenance of each existing structure.

The ICE Guidelines introduces specific terms and actions which are used in this report. These are as follows:

Initial Appraisal

The Initial Appraisal is centred upon checking existing records for completeness and detailing specific needs in terms of further inspection and maintenance by a desk study of records prior to the Condition Survey.

Condition Survey

The Condition Survey is a detailed visual examination of the structure to identify structural form, general material condition and to identify areas worthy of further examination.

Structural Investigation

The findings of the Condition Survey are used to plan the Structural Investigation, which is aimed at deriving the material condition at specific structurally vulnerable positions and/or to record parameters such as cover, carbonation depth, chloride contamination, material strength and reinforcement corrosion activity.

Structural Appraisal

A Structural Appraisal considers the integrity of the asset in terms of its residual load capacity, particularly at vulnerable positions which may exist as a result of inadequate design, inappropriate repair or material deterioration. This appraisal should address the main structure as well as the adequacy of edge barriers.

Maintenance and Repair

The need for Maintenance and Repair will stem from the previous surveys, inspections and appraisals and should be planned and executed in a timely manner, ensuring a solution that is both affordable to the client and correct for the extent of deterioration encountered.

Typical recommendations for the content of the LCP is detailed below although this may need amendment depending on the individual circumstances, and upon the recommendations of the Engineer,

- Daily Surveillance, usually by operations staff
- Routine Inspections, typically every 6 months
- Periodic Initial Appraisal and Condition Survey of key components, including cladding and edge protection, prompting Special Inspections as required at intervals of less than 8 years
- Structural Appraisal at intervals of not more than 16 years[1]

Maintenance and repair works are carried out as circumstances dictate as and when instructed by the Owner/Operator, including routine and protective/preventive works and the recording thereof.

[1] IICE, 2002 footnote 'd' given below Table 5.1 on Page 14 states that 'Shorter intervals than the maximum values given are likely to be appropriate. The Engineer should advise the Owner/Operator taking into account the condition of the car park structure and the defects known to be present'. Given the age and current condition of Temple Gate MSCP 5 years and 10 years are deemed appropriate for the condition surveys and structural appraisals respectively.

SECTION 3

# Description of the Structure

## 3.1 Orientation

Temple Gate MSCP lies with its long axis running in a North West to South East orientation. For the purposes of this report the elevations are distinguished as follows:

- Northeast elevation – facing the Holiday Inn, and Temple Meads Station beyond.
- Southeast elevation – facing the rear of the Peugeot garage (and parallel to the River Avon).
- Southwest elevation – facing Chatterton Square, and Somerset Street beyond.
- Northwest elevation – facing the Derelict petrol station, and Redcliffe Way beyond.

Plans and elevations are provided in Appendix A.

## 3.2 Components and arrangement

Temple Gate Multi Storey Car Park is a 7-storey car park believed to date from the late 1960's or early 1970's; the date of construction is not known. It currently has a secure entrance / exit gate at the southeast elevation, as, above ground level, it is used for contract parking only. The southwest 'half' of the ground floor is 'pay & display' public car park, with a ground-bearing, horizontal concrete floor. Above this level, Temple Gate is of in-situ integral reinforced concrete construction, with some infill cavity walling along the long elevations. The floor slabs are inclined and form the ramps between levels, with a split level arrangement, with a horizontal strip at the northwest and southeast ends forming the turning areas. Therefore the northeast half of the 'ground floor' is actually the ramp rising up to Level 1.

There are 2 stair towers and a lift shaft adjacent to the main stair tower. These comprise reinforced concrete frames with glazed and concrete facades. The stairwell doors were being re-furbished in early 2018.

For the most part, the soffits, columns and interior walls are painted and the decks are bare, with the exception of the exposed top deck. A vehicle and pedestrian restraint system is provided throughout the car park.

Security gratings have been installed to the open sections of the elevations at Ground and First floor levels.

SECTION 4

# Initial Appraisal

The Initial Appraisal comprises a desk study of the existing available records. All documents relating to the Temple Gate MSCP were collated by BCC and subsequently reviewed by CH2M HILL/Jacobs and are summarised in the following sections (in date order).

## 4.1 Drawings

The following drawings were supplied by BCC for information:

Hydrock Drawing C/232/015 TempleGate Car Park, Templemeads, Bristol: Elevations, 9/12/97

Hydrock Drawing C/232/007 TempleGate Multi storey, Temple Meads, Bristol: Ground Floor Plan, 9/12/97

Hydrock Drawing C/232/008 TempleGate Car Park, Templemeads, Bristol: Level One, 9/12/97

Hydrock Drawing C/232/009 TempleGate Car Park, Templemeads, Bristol: Level Two, 9/12/97

Hydrock Drawing C/232/010 TempleGate Car Park, Templemeads, Bristol: Level Three, 9/12/97

Hydrock Drawing C/232/011 TempleGate Car Park, Templemeads, Bristol: Level Four, 9/12/97

Hydrock Drawing C/232/012 TempleGate Car Park, Templemeads, Bristol: Level Five, Draft, 9/12/97

Hydrock Drawing C/232/013 TempleGate Car Park, Templemeads, Bristol: Level Six, Draft, 9/12/97

Hydrock Drawing C/232/014 TempleGate Car Park, Templemeads, Bristol: Level Seven, 9/12/97

The Hydrock drawings are not original design or as-built drawings.

## 4.2 Asbestos Report 2013 (8/2/2013)

A management survey was undertaken at the car park to identify asbestos containing materials (ACM) by MSS Consulting Ltd in February 2013. A Management Survey is defined in HSG 264 'Asbestos: The Survey Guide' as a 'Standard Survey' to locate and assess any suspect ACMs for the purpose of managing asbestos within the building.

The electrical switchgear and the fire hydrant box were not inspected along with the lift shaft.

Asbestos was identified in the survey. Debris on the floor and wall in the Temple Gate ground floor storage cage contained asbestos. A dry riser gasket on the ground floor stair well was also found to contain asbestos.

## 4.3 Asbestos Re-Inspection Survey Report (6/7/2017)

In July 2017 a further asbestos survey was undertaken by MSS Consulting Ltd. A re-inspection of all previously identified asbestos inclusions to assess the current condition and undertake a Material Risk and Priority Assessment in accordance with HSG264 and HSG 227.

The lift shaft was not inspected. Asbestos was identified in the survey. Debris on the floor and wall in the storage cage contained asbestos. Asbestos was found in the electrical distribution adjacent to the storage area in a cable race. A dry riser gasket on the ground floor stair well was also found to contain asbestos.

As most lift brakes produced up until about 2004 contained asbestos the asbestos survey / report for the car park shall be reviewed and an assessment made of whether there is the potential for asbestos or ACM (asbestos containing material) forming part of the lift motor room or equipment.

## 4.4 Gaps in the information

The original as built drawings and structural design calculations were not available for review. No information was available from construction of the car park until 2013 when an asbestos survey was undertaken. It is not clear what work and studies were undertaken during the period.

## 4.5 Information generated in this commission

### 4.5.1 Drawings

Plans and elevations of the car park have been developed by CH2M based on the 1997 Hydrock drawings. Locations of defects in the reinforced concrete components have been marked on these, are provided in Appendix A, and include the following:

673846-TG- 101 Temple Gate Ground Floor Staircase Defects

673846-TG- 102Temple Gate Ground Floor Defects

673846-TG- 103Temple Gate Level 1 Staircase Defects

673846-TG- 104Temple Gate Level 1 Defects

673846-TG- 105Temple Gate Level 2 Staircase Defects

673846-TG- 106Temple Gate Level 2 Defects

673846-TG- 107Temple Gate Level 3 Staircase Defects

673846-TG—108 Temple Gate Level 3 Defects

673846-TG- 109Temple Gate Level 4 Staircase Defects

673846-TG- 110Temple Gate Level 4 Defects

673846-TG- 111Temple Gate Level 5 Staircase Defects

673846-TG- 112Temple Gate Level 5 Defects

673846-TG- 113Temple Gate Level 6 Staircase Defects

673846-TG- 114Temple Gate Level 6 Defects

673846-TG- 115Temple Gate Level 7 Staircase Defects

673846-TG- 116Temple Gate Level 7 Defects

673846-TG- 117Temple Gate South and East Elevations

673846-TG-118 Temple Gate North (East & West) and West Elevations

### 4.5.2 Test data

Information from the site investigation includes chloride test data, reinforcement scans (using radar), carbonation depth and compressive strength measurements. These are included in Appendix B.

### 4.5.3 Digital images

There are also a series of digital images and digital video files which illustrate condition resulting from the inspections undertaken by CH2M. These are not included but are available to BCC on request.

SECTION 5
# Condition Survey

## 5.1 Approach

The condition survey involved a visual inspection using the plans and elevations of the car park to assist in recording defects. All works were undertaken by a team of at least two inspectors. The following sections provide a summary of the features and conditions found in 2017/8, and are presented by structural component or part or by the functional activity required.

## 5.2 Structural frame

### 5.2.1 Columns and beams

There are four lines of columns in the northwest/southeast orientation, spaced at approximately 4.85m centres. These support a total of 12no. beams (spanning transversely, northeast/ southwest) at each level. The beam/column connection at the turning areas at the far ends of each level are slightly more complex due to the off-set levels and arrangement of the longitudinal and transverse beams.

The columns and beams are painted white (see Figure 5-1). The coating is typically in good condition. There are a small number of defect in the beams and columns that relate to, or appear to relate to corrosion of embedded reinforcement. However, there is no evidence of distortion or significant structural damage.

**Figure 5-1. Structural arrangement**
*Typical slab, column, beam, soffit and wall arrangement*

### 5.2.2 Walls

There are lightweight concrete blockwork infill walls to the northeast and southwest elevations. These are likely to have been intended to add to the structural rigidity (i.e. shear resistance) of the structure. The walls are full height (floor to ceiling), and span between the columns and the car park slabs. They are of cavity construction, and were probably intended to be held together with cavity ties.

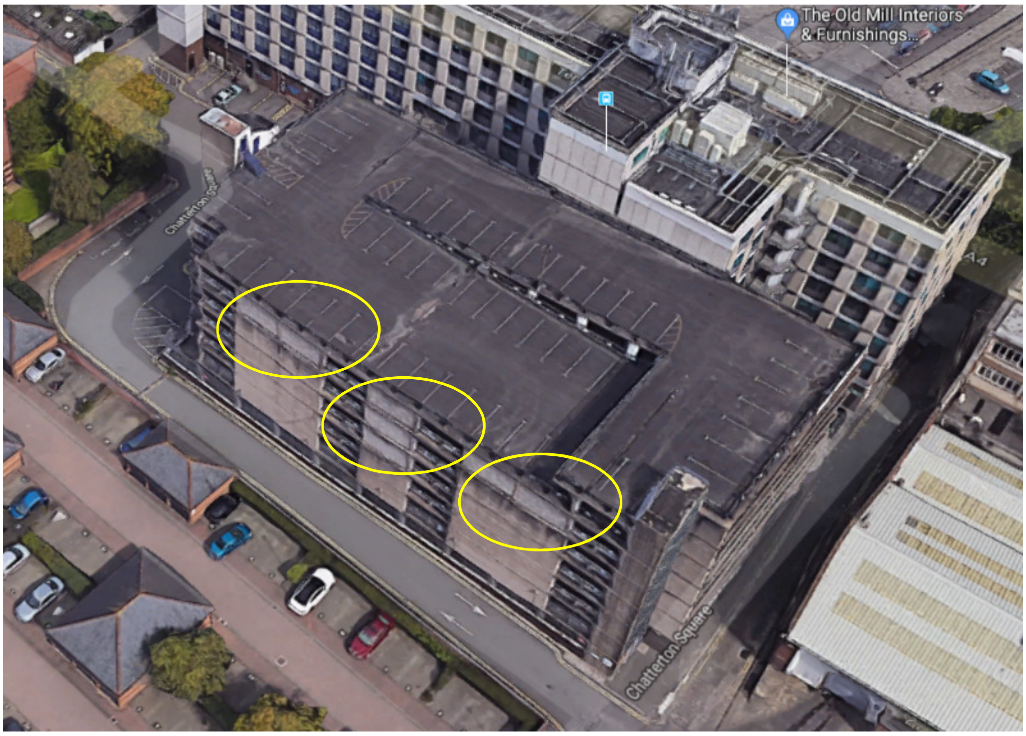



Figure 5-2 Infill walls
*Southwest Elevation Infill Walls (Missing Outer Leafs Ringed)*

To several sections of the infill wall at the upper levels, parts of the outer leafs are missing (see Figure 5-2) and the inner leafs are clearly damp stained. We suspect that corrosion of the cavity ties (where present) may be taking place, which if correct, would likely continue to the remainder of the elevations and hence a risk that requires further investigation.

There is also concern that falling masonry might occur at any time. In light of this, we recommend urgent inspection, using a scaffolding tower, to properly examine the walls for defect and stability. It will also aid the preparation of the specification for remedial works required.

If the walls are found to require replacement, this could present an opportunity to re-clad the elevation with a maintenance-free cladding system such as those shown in Figure 5-3. These would of course incorporate suitable framework to provide the shear resistance required, but with an improved and relatively maintenance-free external appearance.

Figure 5-3 Cladding
*Examples of maintenance -free cladding systems on the market to replace the deteriorating infill walls to the South Elevation*

Elsewhere at high level, heavy soiling and staining is evident, caused by the lack of a suitable drip detail, which is allowing surface water run-off, and to some extent atmospheric pollution, to run down the face of the walls.

The lower aprons of the elevations are clad with cavity masonry incorporating brickwork outer leafs. Local but minor damage to the brickwork is evident, in addition to deterioration of the pointing in areas.

### 5.2.3 Ground bearing slabs

Part of the ground floor split level is a ground bearing slab. Spalling to the concrete surface was found during the inspection, which appeared to result from corrosion of reinforcement bars. Whilst there is no significant risk of structurally significant deterioration, these defects pose a trip hazard which can be expected to become progressively worse and more abundant without treatment.

### 5.2.4 Suspended slabs

Most of the slabs in the car park are supported by the beams, and the slab depth (175mm) can be viewed from within the car park at each split-level. The short spans between beams are approximately 4.85m. There are two longer spans across the aisles and parking bays, each of over 11m span, and a short span at the southwest elevation spanning parking bays only) of under 5m.

The appearance of the top surfaces at each floor are as-expected for a multi-storey car park of this age, with a significant amount of texture remaining from the original concrete construction, plus abundant evidence of road grime, oil and tyre markings. The white lining (delineating turning circles and parking bays) are typically worn.

The condition of the concrete is generally good, but there is some cracking and spalling in the top surface, mostly at Ground level, Level 1 and to a lesser extent Level 2. Only 8% of the total surface area of defects to the deck upper surface occur above Level 2. These defects appear to relate to corrosion of embedded reinforcement.

There are also similar corrosion-related defects to the bottom surface of the slabs (i.e. the soffits). These are often associated with cold joints in the concrete, which appear to be a preferred pathway for moisture to penetrate the slabs.

## 5.3 Stairwells

### 5.3.1 Concrete stair units

The stairs are of pre-cast concrete design, resting on the car park framework at each floor level. They incorporate yellow non-slip nosings, screw fixed to the goings (steps).

Where the landings abut the staircase walls, they are sealed and the landings generally painted. Along the stringers (sides) of the staircases, they do not abut the perimeter walls, allowing cleaning surface water and the like to cascade over and onto the staircase glazing and walls, causing premature deterioration of the steel frames and beams that support the glazing systems. It would be prudent to review this design and perhaps allow for edge protection to the exposed stringers to limit future soiling and corrosion.

In addition to the above, it would be beneficial, from a cosmetic point of view, to paint the stairwells (walls and soffits).

Painted steel balustrades are bolted to the staircases. These appear to be in average condition and would benefit from cleaning as a minimum and re-coating in some locations. The handrailing is discontinuous on the 'outer' perimeter of the stairwell at the internal blockwork wall. Absent sections could to be readily added.

### 5.3.2 Facades

The two staircases to this car park are mostly clad with patent glazing. There are also what appear to be pre-cast concrete cladding units.

The patent glazing system is considered to be original and comprises of:

- Aluminium transoms and mullions
- Georgian wired glazing with rubber gaskets to the framework
- Steel supporting framework, partially embedded in the concrete framework

Overall, the glazing system is tired and damaged in part and at the end of their expected serviceable lives. Our review of each is noted below:

A. Staircase A (Main entrance, incorporating the lift shaft). We noted approximately 22 nr. broken or cracked glazing panes, and two loose gaskets. Overall there is surface corrosion to most of the supporting steel framework and overall the cosmetic appearance is very poor.

B. Staircase B (to the rear southwest corner). The lower (Ground Floor) entrance is hoarded with plywood and cordoned off from first floor level and so it is not in use for ground level access. We noted approximately 10 cracked or damaged glazing panes, most of which appear to be ballistic holes in the glazing. There are a few lose gaskets. The ground level aluminium doorset is damaged and missing ironmongery and therefore not fit for use. Once again, there is surface corrosion to most of the supporting steel framework and overall the cosmetic appearance is very poor.

In light of the above, the glazing systems are in need of substantial refurbishment and repair. Given the extent of the work required, and the general poor cosmetic appearance of the system installed, consideration should be given to replacing all of the façade glazing systems. New systems are likely to have a payback period of five to 10 years, given the life of the existing systems and the need to continually maintain.

The concrete elevations appear to be in reasonable condition. The condition of the cladding fixings should be investigated however, before determining the extent of any refurbishment. Local spalling of the exposed concrete surface (and associated corrosion of reinforcement bars) is evident in part, but we would expect the cladding to be repairable, prior to cosmetic improvement, perhaps including steam cleaning and subsequent application of an anti-carbonation coating.

### 5.3.3 Stair tower roofs

The main stairwell and lift are located on the northwest facing elevation. The stairwell roof consists of upper and lower horizontal roof sections linked by an inclined section, bounded on three sides by a low upstand, and is shown in Figure 5-4. The roof and low upstands are covered with what appears to be sheets of a dark grey mineral felt roofing product. The fourth (lift well) side is bounded by a higher wall with mineral felt sheet extending approximately a quarter the way up the wall. The remainder of the wall is bare concrete. There is some moss and mud accumulation on the roof surfaces, and approximately 80% of the lower roof area is obscured by detritus and standing water.

The roof covering appears to have degraded over time, with what appear to be splits, and blistering in the covering, which has also lost much of the original grit at the surface.

There is an outlet at the southeast corner of the lower flat roof section, providing drainage to a hopper and downpipe.

A metal strip lighting conductor “tape” is present at the perimeter upstand walls. It is detached in places. It may have been used to assist members of the public to climb onto the roof, resulting in this damage. There is also galvanised steel anti-climb strip attached to the upstand facing the car park deck. These elements would need to be removed and re-attached if the weatherproofing were to be replaced. All lightning protection systems should comply with BS 6651 and be designed, installed and tested by specialist lightning protection engineers.

The roof to the lift motor room is a simple flat roof (shown in Figure 5-5) with low (approximately 100mm) perimeter upstands, with a penetration at the southeast corner feeding a hopper and downpipe from the lift core roof which discharges onto the upper flat roof section of the adjacent stairwell roof.

The surfacing appeared to be a continuous mastic asphalt covering to the main roof and vertical and horizontal components of the perimeter upstands. The asphalt appeared to have been overcoated with a light grey liquid applied coating. Condition appeared good, with no obvious damage or delamination to the surface.

The roof is partly obscured with silt, had standing water over 80% of the area, and the upstands were heavily coated with algae.

Figure 5-4 Main stairwell roof
*Deterioration of roofing material, standing water and detachment of lightning strip from file GOPR0427*

Figure 5-5 Lift motor room roof
*Roofing material in good condition, standing water and lightning strip from file GOPR0428*

The stairwell at the south corner of the car park comprises an upper and lower flat roof sections with an intermediate inclined roof section (Figure 5-6). There are no perimeter upstands. There is a lighting tape attached to the perimeter, and a galvanised steel anti-climb strip at the top of the lowest section of wall facing the car park.

The roof was formed of concrete which was coated with what appears to be a thin (<5mm thick) bituminous system, possibly some form of bituminous felt. This surfacing has degraded heavily, has disintegrated or been removed, or is otherwise extensively damaged on the horizontal roof sections, and to a lesser degree the inclined surface.  The whole roof needs to be re-surfaced, which requires removal and re-attaching the lighting protection tape and anti-climb strip.

Figure 5-6 Southwest corner stairwell roof
*Roofing material in degraded condition, and lightning strip from file GOPR0429*

## 5.4 Foundations

The foundations are not visible without excavation, which is outside of the remit of the survey completed to date, and therefore have not been inspected. However, there is no evidence of settlement, movement or tilting of the structure.

## 5.5 Edge protection

The vehicle containment is provided by galvanised steel un-tensioned corrugated beam sections. These are variously attached (bolted) directly to the reinforced concrete or attached to steel “U” channel post sections, bolted to upstands in the floor slab.  Pedestrian containment is provided by galvanised steel sections located above the corrugated beam. This includes a flat section at mid-height and top “L” section, again bolted either directly to the columns (where present), or to the “U” channel post sections (where not).

There is no vehicle restraint on the ground floor short southeast elevation; this appears to be provided by a solid half-height brick wall.

The condition of the edge protection is generally good, with only localised corrosion of the main elements. The condition of the baseplates and holding-down bolts for the posts is more variable, as might be expected for a car park of this age. There is some evidence of corrosion on the plates and bolts. Neither the length of the bolts nor the engagement depth is known, nor the condition of the bolts below the baseplate.

The existing edge protection does not meet current standards for the following reasons:

- the rigid post supports (steel C-sections) are incapable of accommodating the current vehicle impact loadings,
- the barriers are easily climbable, and of insufficient height, and
- the spacing between the elements permit the passing of a 100mm diameter ball, and as such the barrier fails to prevent children from accidently endangering themselves.

The edge protection could be replaced with a new vehicle and pedestrian barrier either by removing the existing barriers and installing a new modern code-compliant edge protection along the same alignments, or by installing a new edge protection system in front of the existing system, fixing to the deck instead of the columns. Removing the existing and installing a new ‘rigid’ system would be more expensive than a new ‘flexible’ system due to the reduced post spacing and the need to remove the current barrier system.

Installation of new 'flexible' system in front of the existing will encroach on the bin depths (depth of parking spaces) and of the aisles, typically by 300mm per installation. Therefore the aisle widths could be reduced by up to 600mm, and the aisles are already below the recommended width for two-way circulation.

## 5.6 Drainage

The drainage in the car park relies on the sloping deck sections transporting surface water downslope to shallow cut-off channels formed in the deck surface. The deck has a local deepening to accommodate the surface indentation forming the channel. Each channel appears to effectively intercept water tracking down the full width of the ramps, and are sloped toward the external perimeter, allowing water to drain through a grating and into a series of metal down-pipes to ground level. The pipework is intact, but leaking slightly in some locations. The pipework is painted, but the coating has degraded and could be re-coated to improve the appearance.

## 5.7 Lift motor room

The lift motor room is accessible via a locked door from the top deck of the car park (Image 5-7). The room is weather tight and appeared in good condition, with no evidence of water ingress through the roof or walls. The floor covering appeared to be cracked but not delaminating.

Figure 5-7 Lift motor room
*Room in good condition with no obvious sources of water ingress*

## 5.8 Entry / Exit layout / visibility for new POF system

The ground level access was inspected and a proposal prepared for re-modelling the layout for POF. This was included in the Draft Issue of this report. After review with BCC Parking Services in March 2018 this section has now been removed as POF is no longer a preferred option. Should 'pay and display' be implemented it is understood that BCC will consider removal of the existing gate and entry/exit system at ground level.

# 5.9 Retaining secure parking

The following sections were prepared in response to the requirement to relocate existing contract parking spaces to higher levels in the car park. This is equally relevant for POF and 'pay and display' should either option be adopted. Options that provide the same level of security as users currently enjoy have been considered. However, this clearly requires additional expenditure, and is not necessary if no physical barrier is required. It is noted that BCC plan to introduce additional CCTV as part of any new parking arrangements.

## 5.9.1 Vehicle gate

The current sliding gate which secures the contractor parking could be removed and re-installed at a new location. The preferred location would be part way along a ramped deck higher in the car park.

The gate would need to be placed at or beneath a beam to allow the fixings to be installed away from the deck slab which is only 175mm thick. Structural calculations should be undertaken to check the additional load cases on the frame; the relatively light loading is not expected to be a problem. The existing "Reserved Parking" on the beam at ground floor entrance may need to be painted over (dependent on the future location of 'Holiday Inn' parking allocation.

Moving the current system has the advantages of recycling the main parts of the gate and control/access system. There will be no major change in hardware for the current users of the system (and importantly the contract parkers). However, the gate will still be a pinch point in the car park due to its current design which restricts the width of the driving aisle to approximately 5m. This width is further reduced by the need for islands, on both sides of the barrier, for the keypad and card reader. The current layout forces exiting cars into the other lane preventing cars from comfortably entering and exiting at the same time.

It is possible that re-use of some or all of the equipment would be practical in a 10-year plan, if a suitable contractor was engaged and willing to take on the commitment to re-commission a previously operated gate access system. It is possible that after re-location the system would require a greater level of maintenance. Therefore it would be more prudent to install completely new equipment for a 20-year plan.

One option investigated was using bi-fold gates on the horizontal deck area around staircase A. This would create a pinch point with cars queuing to enter and exit, and we have excluded this as a realistic option.

Using a telescopic sliding gate could optimise access by increasing the available trafficable width (i.e. the full width of the aisle). Telescopic gates can slide on runners from the beam or tracks in the deck. Number plate recognition could also be added to the system allowing easier access and egress for users.

## 5.9.2 Pedestrian access

Consideration has been given to installing a secure entrance system for contract parking at higher levels in the car park. This requires both stair towers and the lift to be made secure, unless the secure perimeter is taken as being the fire door to a particular level, and the door is made secure. The simplest option would be to install electro-magnetic door locks to the relevant fire door sets, and new access controls either side of the doorway. This removes the need to install additional access restrictions on the stairs and lift, but permits all car park users access to the full height of each stair tower. It would be possible to re-locate the existing secure entrance door on the ground floor to a higher level, but it is not suitable as a fire door.

Consideration must be given to removing the barrier at the base of stairwell B so that this becomes a viable exit from Level 1 and above.

# 5.10 Removal of existing shutters to each deck

There are roller shutters on the north side of the car park at level 2 and level 4. Currently these roller shutters are welded in the open position. It is feasible to remove the roller shutters only or the concrete partition wall across the parking space as well (following structural calculations).

Removing only the roller shutters will require minimal works. Making good will require cutting back fixings and painting the soffit. Removing the partition wall will require more work to make good. such as planing the deck (to smooth out the surface) and painting the soffit. Some concrete repairs may be required.

# 5.11 Aesthetic upgrade of external elevations

Any upgrade to the elevations should be considered in conjunction with the agreed actions for the glazed facades, the concrete parts of the stair and lift towers, the missing perimeter blockwork and the actions to be taken at the perimeter parapets. As such, any external upgrade theme is likely to involve cleaning, coating and/or addition of cladding.

# 5.12 Limitations of current layout

We have reviewed the current layout of the carp park against the recommendations set out in "Design recommendations for multi-storey and underground car parks (Fourth Edition)" by The Institute of Structural Engineers. The driving aisle is approximately 6.6m wide where the recommendation for 2-way aisle is 6.95m. The narrowest points of circulation in the car park are between the main columns at the horizontal sections at the short ends of the car park, where vehicles turn 180 degrees between the two adjoining ramps where the width reduces to less than 6m. This is the recommended width for one way traffic, and observation of the current usage indicates that drivers do not pass each other at this point. The situation will only become more complicated with higher turnover of the car park i.e. when operating as POF.

At the moment there is some overhang of cars in to the driving aisle reducing the trafficable width of the driving aisle and the available space for maneuvering (parking and turning around). This is because the bay depths are not long enough for some modern cars particularly when not parked tight against the vehicle barrier. As noted in Section 5.5, any increase in the space occupied by the vehicle and pedestrian barrier will exacerbate the problem.

The current width of the bays is less than 2.3m which is the recommended width for a long stay car park. For a mixed use car park (which is anticipated in a POF), the recommended width of the bay is 2.4m. This is not possible on the south west side of the car park due to the column spacing, without halving the number of spaces. Elsewhere the reduction is spaces could be less.

There is the option that the layout of the car park can changed to be more accommodating to those using it as a POF facility. Changes to the layout of spaces and aisles could improve circulation and usability, but would reduce the number of parking spaces significantly. This could help make the car more attractive and potentially command a premium rate.

In the light of the above, further consideration is recommended prior to agreeing the recommended maintenance and improvement works.

SECTION 6

# Structural Investigation

## 6.1 Approach

We understand that there are no contemporary construction drawings, structural drawings, previous records of structural appraisal, or records of maintenance and repair activity for this structure. On this basis, a structural investigation was designed and undertaken, recording parameters such as chloride ion content, cover depth, carbonation depth and compressive strength.

The structural investigation was aimed at deriving the material condition and properties so that load assessments could be undertaken, at specific structurally vulnerable positions. It was also aimed at assessing the overall condition, type and extent of deterioration, and risk of future deterioration, which are important factors in assessing the potential demand for repair and maintenance.

Is was not possible to undertaken a full assessment of all elements of the car park at all levels; columns, beams and slabs have been sampled and tested at specific locations only.

This section of the report documents the findings of the site investigation and associated laboratory testing.

CH2M HILL/Jacobs appointed a specialist contractor, EDS to undertake the sampling and testing work. Intrusive sampling was carried out at 24 locations and included:

- measurement of minimum cover depth to reinforcement;
- carbonation depth,
- incremental dust drilling for laboratory testing for chloride content, and
- 'break outs' to locally remove concrete cover to expose a reinforcing bar for calibration of instruments and visual confirmation of corrosion condition.

In addition, three, 50mm diameter core samples were also cut and removed from beam soffit, column and deck positions. These samples were conveyed to a specialist laboratory to determine compressive strength and density.

These sample and test locations are shown in Table 6.1 below:

TABLE 6.1
**Sample and Test Locations**

| Location reference | Level | Element | Testing undertaken |
|---|---|---|---|
| BO1 | Ground | Column | Cover, Carbonation, Breakout |
| BO2 | Ground | Column | Cover, Breakout |
| BO3 | Ground | Column | Cover, Breakout |
| BO4 | 3 | Column | Cover, Breakout |
| BO5 | 3 | Deck | Cover, Breakout |
| BO6 | 3 | Beam | Cover, Breakout |
| BO7 | 3 | Column | Cover, Breakout |
| BO8 | 3 | Beam | Cover, Carbonation, Breakout |
| BO9 | 3 | Column | Cover, Carbonation, Breakout |
| TA1 | 3 | Deck | Chloride |
| TA2 | 3 | Deck | Chloride |

TABLE 6.1
**Sample and Test Locations**

| Location reference | Level | Element | Testing undertaken |
|---|---|---|---|
| TA3 | 3 | Deck | Chloride |
| TA4 | 2 | Deck | Chloride |
| TA5 | 4 | Deck | Chloride |
| TA6 | 4 | Deck | Chloride |
| TA7 | 4 | Deck | Chloride |
| TA8 | 2 | Deck | Chloride |
| TA9 | 2 | Deck | Chloride |
| TA10 | Ground | Deck | Chloride |
| TA11 | Ground | Deck | Chloride |
| TA12 | Ground | Deck | Chloride |

Table Notes

Cover = Covermeter depth; Breakout = Break out; Breakout = Depth of Carbonation; Chloride = Chloride drilling (3 depth increments)

All drilled sample holes, core holes and break-out areas were reinstated using a BS EN 1504-3 Class R4 repair material.

## 6.2 Record of defects

### 6.2.1 Visual and Hammer Tap Survey

All visible areas were checked for defects and accessible areas where defects were found were checked for debonding of the cover concrete from the reinforcing bars using a light chipping hammer and noting the audible response. A 'drummy' note indicated hollowness whilst a 'ringing' signified a sound bond to the bars.

A summary of concrete defects identified is presented in the Tables 6.2 and 6.3.

TABLE 6.2
**Concrete delamination or spalling defects**

| Element | No of defects | Total estimated area (sqm) |
|---|---|---|
| Slab | 117 | 15.32 |
| Slab soffit | 108 | 8.18 |
| Upstands | 37 | 1.01 |
| Column | 3 | 0.09 |
| Elevations | 60 | 2.14 |

TABLE 6.3
**Concrete defects by level**

| Element / Level | No of defects by level | | | | | | |
|---|---|---|---|---|---|---|---|
| | Ground | 1 | 2 | 3 | 4 | 5 | 6 |
| Slab | 23 | 47 | 19 | 6 | 2 | 12 | 5 |
| Slab soffit | 29 | 9 | 17 | 25 | 28 | | |
| Upstands | | 3 | 15 | 6 | 5 | 1 | |
| Column | | | | | 3 | | |
| Elevation | 7 | 6 | 24 | 2 | 19 | | 3 |
| **Total** | **59** | **65** | **75** | **39** | **57** | **13** | **8** |

# 6.3 Reinforcement and cover

## 6.3.1 Cover Meter Survey

The depth of concrete cover to the steel reinforcement embedded in the structure was measured using an electromagnetic cover meter instrument, which operates in general accordance with the requirements given in British Standard BS 1881: Part 204.

A Hilti X Scan PS 1000 scanner was also used to locate and measure the cover to the steel reinforcement. The minimum recorded cover depth, irrespective of orientation, was recorded within each 600mm x 600mm grid area and at each break out. A summary of the cover depths detected is shown in Table 6.4.

## 6.3.2 Concrete Breakouts

Concrete breakouts were undertaken within test areas BO1-9, using an electrical- powered percussion drill and breaker with chisel points in order to visually confirm the bar type, actual cover depth and the corrosion condition.

The depth of cover was assessed at sixteen test areas: 8No. on the deck, 6No. on the columns and 2No. on beam soffits.  The results are shown in Tables 6.5.

TABLE 6.4
**Minimum Cover detected by covermeter survey**

| Test area reference/element | Minimum Cover detected by covermeter survey |
|---|---|
| Scan 1/Deck (Level 3) | 150 |
| Scan 2/Deck (Level 4) | 55 |
| Scan 3/Deck (Level 4) | 150 |
| Scan 4/Deck (Level 4) | 25 |
| Scan 5/Deck (Level 5) | 65 |
| Scan 6/Deck (Level 5) | 35 |
| Scan 7/Deck (Level 5) | 35 |

TABLE 6.5
**Results of break outs**

| Test area reference/element | Bar orientation | Actual cover at break-out (mm) | Bar type/diameter (mm)/condition |
|---|---|---|---|
| BO1/Column (Ground) | Horizontal<br>Vertical | 40<br>50 | Textured/10/ no corrosion<br>Square twist/32/no corrosion |
| BO2/Column (Ground) | Horizontal<br>Vertical | 45<br>55 | Square twist/ 10/ no corrosion<br>Square twist/ 32/ no corrosion |
| BO3/Column (Ground) | Horizontal<br>Vertical | 55<br>65 | Plain round/10/ no corrosion<br>Square twist/ 32 / no corrosion |
| BO4/Column (Level 3) | Horizontal<br>Vertical | 35<br>?? | Plain round/10/no corrosion<br>Square twist/ 25 / no corrosion |
| BO5/Deck (Level 3) | Transverse??<br>Longitudinal?? | 60<br>76 | Square twist/ 16 / no corrosion<br>Square twist/ 16 / no corrosion |
| BO6/Beam (Level 3) | Link<br>Main span | 50<br>60 | Plain round/10 minor surface corrosion<br>Square twist/25 minor surface corrosion |
| BO7/Column (Level 3) | Horizontal<br>Vertical | 50<br>60 | Plain round/10/ no corrosion<br>Square twist/ 25 / no corrosion |
| BO8/Beam (Level 3) | Link<br>Main span | 55<br>65 | Plain round/10/ no corrosion<br>Square twist/ 25 / no corrosion |
| BO7/Column (Level 3) | Vertical?? | 45 | Square twist/ 25 / no corrosion |

# 6.4 Carbonation, chlorides and strength

## 6.4.1 Carbonation Depth

The alkalinity of concrete is reduced by atmospheric carbon dioxide and this is an ongoing process which penetrates from the surface of the concrete towards the embedded steel. Where this carbonated layer reaches the reinforcement, the risk of corrosion increases.

The reduction in alkalinity of the concrete is measured using a spray-applied phenolphthalein indicator solution to a freshly broken concrete surface in general accordance with Building Research Establishment Information Paper (BRE IP) 6/81 and Digest 405.

The depth of carbonation is indicated by a distinct colour change between clear (carbonated) and pink (un-carbonated) concrete. The depth of carbonation can then be measured from the concrete surface. The carbonation depth test results are recorded in Table 6.6.

TABLE 6.6
**Results of Carbonation Depth Survey**

| Test area reference/element | Measured carbonation depth | Concrete cover depth at breakout | Cover depth >carbonation depth (Yes/No) |
|---|---|---|---|
| BO1/Column | 5 | 40 | Yes |
| BO8/Beam | 15 | 55 | Yes |
| BO9/Column | 15 | 45 | Yes |

### 6.4.2 Chloride Ion content of the decks

At selected deck locations, drilled dust samples were collected using a rotary-percussive drill and large diameter masonry bit in accordance with recommendations detailed within BRE-IP 21/86.

The concrete dust was collected in approximate depth increments as follows: 5-20mm, 20-35mm and 35-50mm. The outermost 5mm was assumed to be weathered and therefore non-representative and discarded.

The dust samples were then submitted to a UKAS accredited laboratory, Quartz Scientific Ltd, for chemical analysis for determination of chloride ion content in accordance with the procedures detailed within BS 1881: Part 124. The cement content was not evaluated during this survey but an assumed cement content value of 14% was used.

The laboratory test certificates are presented in Appendix B. The data was assessed using the criteria given in BRE Digest 444: Part 2 for a 40 year old structure (assumed damp with pH>10), and against the threshold value above which the levels of chloride ion are considered to induce corrosion (i.e. 0.4% by weight of cement for chloride). Given its age it is feasible that cast-in chlorides are present, however, this not believed to be the case.

The data shows significant elevations over the expected chloride content in the outer 50mm of the deck slabs. Chlorides could have originated from the use of de-icing salts spread across the car park or tracked in by vehicles during winter periods.

There are high levels of chloride contamination in the outer 50mm of the ground level (including both the ground-bearing floor slab and the suspended deck from the existing entrance up to Level 1). Given the incidence of 23No defects in the Ground Floor and 47No on Level 1, it is highly likely that chloride-induced reinforcement corrosion is occurring in multiple areas.

Variable levels of chloride were found in Level 2, varying from Moderate to Extremely high. This was in combination with 19No. defects in the deck. At level 3 and 4, the chloride content in the deck increments are lower, and vary from Low to High, but are still at levels that are associated with chloride-induced reinforcement corrosion. However, only 6 defects were recorded in the deck of level 3, and only 2 on level 4.

### 6.4.3 Core Sampling

Three concrete core samples of 50mm nominal diameter were extracted using a wet, diamond-tipped coring rig, which incorporates a water flush for bit cooling and sediment removal. The core samples were extracted in general accordance with the methods described in BS EN 12504-1:2009.

The core samples were dispatched to a UKAS accredited laboratory, Sandberg LLP for determination of compressive strength and density. Each core sample was prepared, examined, measured and tested in accordance with the methods described in BS EN 12504-1:2009 and BS EN 12390-7:2009 to give the corrected in-situ strength and density (water displacement method).

The core compressive strengths ranged from 64.0 $N/mm^2$ to 68.2 $N/mm^2$, as shown in Table 6.7.

TABLE 6.7
**Results of Compressive Strength Tests**

| Element | Mean Diameter (mm) | Saturated Density (Kg/m³) | Corrected in-situ Strength (N/mm²) |
|---|---|---|---|
| Beam | 44 | 2450 | 64.0 |
| Deck | 44 | 2430 | 60.1 |
| Column | 44 | 2450 | 68.2 |

A copy of the test certificate is provided in Appendix C.

# 6.5 Discussion of main findings

## 6.5.1 Cover and protection to reinforcement

The columns and beams in the car park are characterised by dense, strong, well compacted concrete equating to significant amounts of high quality concrete cover. There is very little evidence of active corrosion of the reinforcement exposed in these elements. The depth of cover far exceeds the carbonation depth (5-15mm), suggesting there is little risk of carbonation-induced reinforcement corrosion to the main elements of the structural frame. However, there is some localised damage which may have resulted from particularly low cover, or from localised ingress of chlorides (see 6.5.2).

The minimum cover depths from slab ranged from 35mm to 150mm, with a mean value of 46mm (excluding two readings of 150mm).

## 6.5.2 Chlorides and deck reinforcement

Large areas of the Ground floor, Level 1, and Level 2, deck are expected to be actively corroding or likely to initiate macro-cell corrosion activity in the future. Repair of damaged areas is necessary to retain strength in the deck slabs, but concrete repair is unlikely to provide a long-term solution without additional corrosion-control techniques and repair in combination with a new water resistant surfacing.

The extent of corrosion activity is likely to be lower, and more restricted in area on levels 3 and 4, as demonstrated by the much smaller number of defects currently manifested in the deck. However, the chloride sample data indicates a significant ongoing risk of chloride-induced corrosion which is best mitigated by action in the short term, by introducing a new water resistant surfacing.

Sporadic and localised chloride contamination is expected on Level 5 and 6, where there are also a relatively small number of deck defects.

SECTION 7
# Structural Appraisal

## 7.1 Details of Appraisal

The purpose of the structural appraisal is to assess the current condition, safety, structural adequacy of the existing primary and secondary structural components against current requirements and to forecast future trends and needs for inspection and repair.

## 7.2 Basis of the Original Design

It is considered likely that based on the age of the car park the original design would have been to: CP 114: The Structural Use of Reinforced Concrete in Buildings, or possibly CP 110: Code of Practice for the Structural use of concrete, as shown in Table 7.1.

TABLE 7.1
**Development of design codes**

**Table 1.1** Development of Codes of Practice since 1934

| *Code* | *Steel stress (working load)* | *Load factor* | *Deflection* | *Cracking* | *Comments* |
|---|---|---|---|---|---|
| 1965 CP116, CP114 | $0.55f_y$ ($230N/mm^2$) | 1.8 | Warning+ expanded span/depth | Warning | Concrete—statistical control for quality |
| 1972 CP110 | $0.58f_y$ ($267N/mm^2$)* (without redistribution) | 1.6*–1.8 | Span/effective depth ratios | Bar spacing rules | Ditto |

*Table 7.1 Development of codes*

## 7.3 Investigation Work

Due to an absence of structural design or construction information it was necessary to undertake localised intrusive investigation work to ascertain as-built reinforcement arrangements. Key structural elements were identified and localised breakout work and GPR surveys undertaken. Table 7.2 summarises the reinforcement encountered in the locations investigated. These reinforcement arrangements were used as part of the structural appraisal.

TABLE 7.2
**Summary of existing reinforcement content for key structural elements**

| Element Description | Size (mm) | Reinforcement Intent |
|---|---|---|
| Typical Deck | 175mm thick slab | 25mm square |
| Transverse Beams | 392x325 | Four 25mm square twist bars<br>Links 10mm round bars |
| Longitudinal Beams | 696x487 | Nine 25mm square twist bars<br>Links 10mm round bars |

TABLE 7.2
**Summary of existing reinforcement content for key structural elements**

| Element Description | Size (mm) | Reinforcement Intent |
|---|---|---|
| Central Column | 690x380 | Eight 25mm square twist bars<br>Links 10mm round bars |
| North Edge Columns | 384x310 | Four 25mm square twist bars<br>Links 10mm round bars |
| Column | 535x304 | Four 25mm square twist bars<br>Links 10mm round bars |
| South Edge Column | 386x321 | Four 25mm square twist bars<br>Links 10mm round bars |

## 7.4 Analysis

The car park was analysed as a plane frame with each member representing 16’ (4.877m) width of floor. Assessment criteria are as follows:

- Concrete strength 60N/mm$^2$
- Steel yield strength 425N/mm$^2$, main bars are all 25mm square twisted, equivalent to 28.2mm diameter
- Concrete density 25kN/m$^3$
- Car park loading 2.5kN/m$^2$ assumed (BS EN 1991-1-1:2002 Table NA.6)
- Floor members modelled as T beams (inches): breadth 192 depth 22 t flange 7 t web 15 (floor 7” thick)
- Column member sizes variously 15” x 12”, 21” x 12” or 15” x 27”

At the car park ends, the two semi decks are aligned vertically (Figure 7-1) while at mid length the decks are out of phase by half a storey height (Figure 7-2).The vertical height is 2.718m per storey.

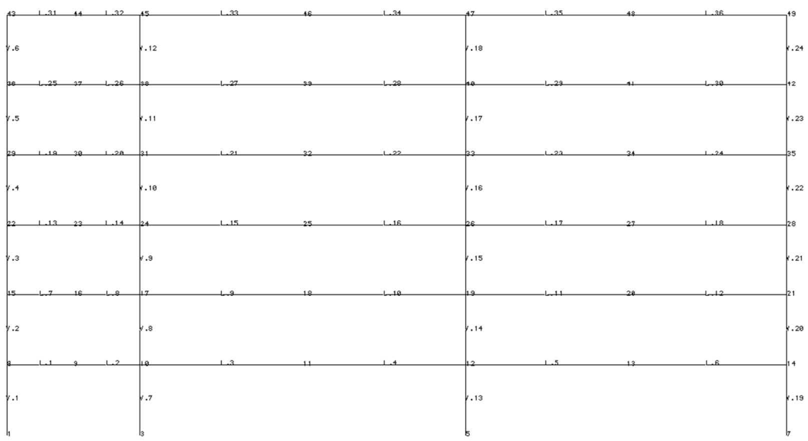


*Figure 7-1*

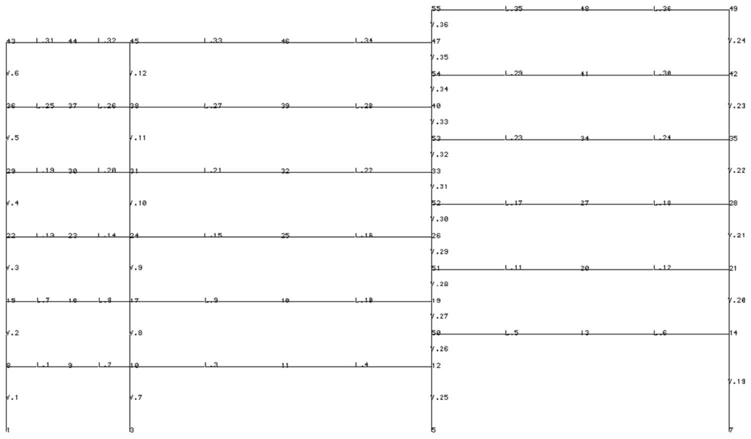


*Figure 7-2*

Permanent loads and live loads are applied to every part of structure, using two computer models in Leap5 classic. The individual member loads are obtained and factored by spreadsheet for ULS.

The worst case scenarios were obtained and applied to the elements.

### 7.4.1 Application of load to elements

In accordance with BS 8110 Figure 3.12 and Table 3.18, the slab is divided into columns strips and middle strips. Since the drop width 15” is less than one third of the transverse span (192”), the effects of drop are ignored.

### 7.4.2 Capacity of elements

The beams have four bars in the top and bottom faces all 25mm square (equivalent 28.2mm diameter).

The deck slabs have bars in the tensions faces also 25mm square at 9” or 10” pitch. In some peripheral areas where the span is less, the steel was found to be 16mm square (equivalent to 18mm diameter). Cover to main reinforcement is taken as 50mm. Links in the beams are 10mm round bars (fy=250N/mm$^2$) at estimated 12” pitch.

The results of capacity and applied loads are shown in Table 7.3.

TABLE 7.3
**Capacity and applied loads**

| | Capacity | Applied load | Utilisation factor |
|---|---|---|---|
| Sagging of column strip | 376.6kNm | 286.6 | 0.76 |
| Sagging of middle strip | 86kNm/m x 2.438 = 209.7kNm | 234.5kNm | **1.12** |
| Hogging of column strip | -1157.7kNm | -543.4kNm | 0.46 |
| Hogging of middle strip | -209.7kNm | -181.1 | 0.86 |
| Shear of column strip | 211.8kN before enhancement | 254.4kN | 1.20 before enhancement* |
| Shear of column strip 3d from an end | 211.8kN | 196.2kN | 0.93 |

Note: * analysis including enhancement has an acceptable utilisation factor

### 7.4.3 Longitudinal beams over end turning areas

The end turning bay is modelled separately where two transverse beams are supported within the span of a longitudinal beam. The latter has increased dimensions of 27” wide and 19½” downstand below the deck slab soffit compared to the beams in the remainder of the car park.

The plan area is modelled as a grillage plane as shown in the diagram below. The red lines represent the transverse beams. The green line shows the deeper beam. The model shows four bays at the west end of the car park, representing about 36% of the area of one floor. The entire surface area has a uniform live load of 2.5kN/m$^2$.

The beam results are as follows:

TABLE 7.4
**Beam Utilisation**

| | Capacity | Applied load | Utilisation factor |
|---|---|---|---|
| ULS sagging bending moment | 787kNm | 624kNm | 0.79 |
| Coexisting ULS shear force applied | 317kNm | 338kN | 1.07 before enhancement* |

Note: * analysis including enhancement has an acceptable utilisation factor

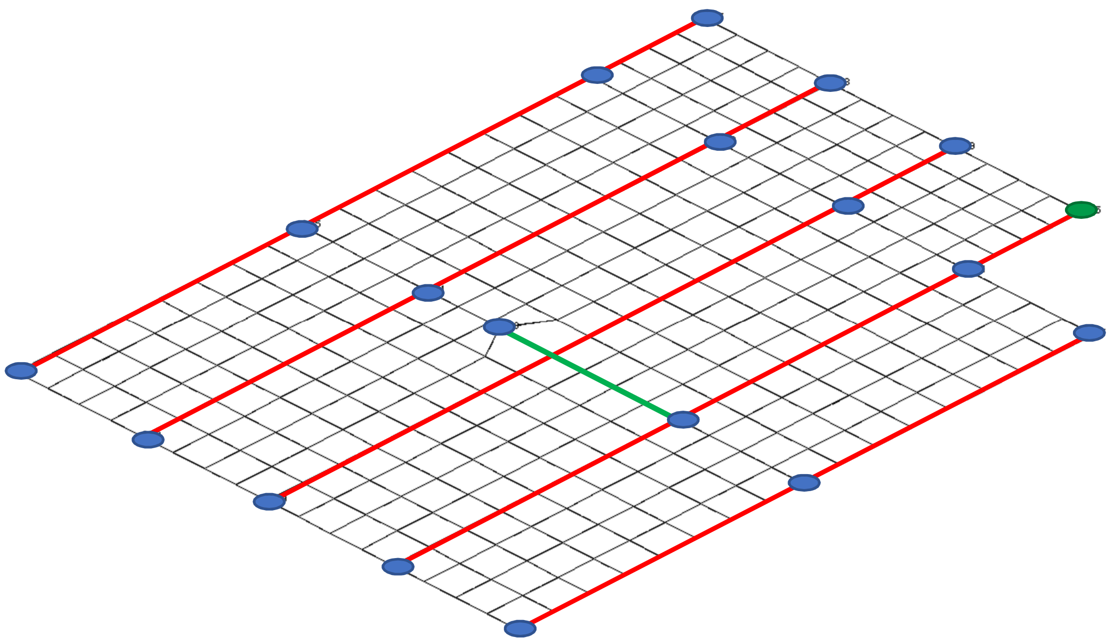


*Figure 7-3*

### 7.4.4 Columns between deck floors

The plane frame model was able to find the vertical loads and bending moments (in one plane) for three column sizes and maximum ULS stresses are as follows:

| | | |
|---|---|---|
| 15” x 12” (grid A) | 1723kN | stress 45.8N/mm$^2$ |
| 15” x 27” (grid B) | 3974kN | stress 43.9N/mm$^2$ |
| 21” x 12” (grid C) | 2831kN | stress 36.1N/mm$^2$ |
| 15” x 12” (grid D) | 634kN | stress 8.8N/mm$^2$ |

## 7.5 Progressive Collapse

Current design standards and the Building Regulations require consideration of progressive collapse and design of key elements. Based on the age of the structure it may have been designed to CP114 and before the 1970 amendment to the Building Regulations brought in after the 1968 Ronan Point disaster, but prior to the issuing of CP110 in 1972 which contained the first detailed requirements for its prevention.

Collapse may occur as a result of a sustained fire beneath the slab, which exceeds the slab's fire resistance. Vehicle impact on a column could also result in collapse. The columns at the perimeter of the car park are of concern as are the internal columns in the turning areas at each end. Given the uncertainty as to the resistance of the structure to progressive collapse, consideration should be given to undertaking further structural analysis and if necessary protecting these columns.

## 7.6 Conclusion and Recommendations

From the above analysis, and based on the limited investigation undertaken to date, it is concluded that there are some areas where the capacity of the frame and decks are not proven to be as large as would be expected. The key consideration is therefore whether the structure is inadequate for the anticipated full design load, or whether we have simply not yet undertaken sufficient investigation to identify all the reinforcing bars in the beams, columns and slabs. Given that there is currently no evidence of structural distress in the structural components of the car park, and it has operated for at least 45-years, it is highly likely that the car park as currently operated is not overstressed. It is also likely that the limited investigation to date has not identified all reinforcing bars present. Changing the operation of the car park to POF does however result in a likely increase in loads, as there is likely to be a higher density of parking on some decks and overall, and a larger number of vehicle movements per day. This, in combination with gradual reduction in capacity associated with future reinforcement corrosion, means that the risk associated with the uncertainty in the load characteristics of the structure is likely to increase in the future. It would therefore be prudent to undertake a further phase of investigative works of the structural detailing at critical locations. These are:

- Centre spans of decks, and
- Columns vulnerable to vehicular impact, and
- Columns at different levels in the car park.

SECTION 8

# Life-care Recommendations

## 8.1 The Plan

The Initial Appraisal, Condition Survey, Structural Investigation and Structural Appraisal have been used as the baseline for the development of a LCP. In developing recommendations it has been assumed that the requirement is to upgrade the structure to near modern standards as far as is reasonably practicable and then maintain it in its current condition for the foreseeable future. The main elements of the recommendations for the content of the LCP, including the inspection and recommendations, are identified in Table 8.1.

## 8.2 Routine Inspections

Routine inspections should be undertaken on 6-monthly cycles and should include the following aspects: visual inspection of key elements (structural frame, masonry, drainage etc). These inspections should be based on a checklist including but not limited to the items given in Table 8.1 mentioned above.

## 8.3 Condition Surveys

Following the condition survey report herein, condition surveys should be carried out at a maximum interval of 5 years. The proposed dates for these are given in Table 8.1. Items to be considered in future condition surveys should be based on the findings of the intervening inspections and the survey works undertaken and described in this report. The results of each future condition survey should be used to re-calibrate the LCP.

## 8.4 Structural Appraisals

Based upon the findings of the limited structural appraisal herein, future structural appraisals should be undertaken at 10 year intervals. The proposed date for this activity is given in Table 8.1. Items to be considered at that time shall rely upon contemporary condition and special inspection information.

## 8.5 Record Keeping

All existing documents, such as those listed in Section 5 and all other relevant documents created in the future, should be recorded. These will form the basis of the historical records that need to be kept as part of the Life-care Plan. All other existing information, such as test reports, calculations, drawings and photographs, should also be added to this record.

To assist in the keeping and updating of the records, the following main categories should be listed:

1. Document title;
2. Document type;
3. Reference number;
4. Date produced;
5. Storage location;
6. Life care Plan action;
7. Other comments.

The record should be updated whenever work is carried on the car park. It is recommended that this responsibility for updating and keeping the records is given to a designated person.

**Table 8.1**

**Inspection and Investigations of Elements for Temple Gate MSCP (based on Table 5.1 of ICE 2002 Recommendations)**

| Action | Work by | Report to | Required | Scope |
|---|---|---|---|---|
| Daily surveillance | On-site staff | Property manager | Daily | Record and report any incidents, signs of damage/collisions or failures/breakdown of equipment.<br>To include lighting, signage, security, drainage, columns, decks, walls, soffits, beam, etc. |
| Routine inspection | Inspector and/or Engineer | Property manager | Every 6 months with an Engineer conducting at least one inspection per annum | **Deck, soffits, Structural Elements:**<br>Check beams, columns and deck soffits for new calcite, rust staining, damage, cracking or spalling.<br>Check and report any movement, damage or deterioration and loose material.<br>Check for new sites of leakage to the soffit.<br>**Drainage**<br>Check for signs of damage or new seepage from connections, rodding eyes, etc.<br>**Handrails**<br>Check holding down bolts and report any missing and or any signs of deterioration. Check for evidence of impact. |
| Condition Survey | Engineer | BCC | 2023, 2028 | Carry out future condition surveys based on findings from this report, plus any subsequent inspections. |
| Structural Appraisal | Engineer | BCC | 2028 | Items to be considered in further Structural Appraisal should be based on the findings of the previous Structural Appraisal plus also all subsequent inspection and survey works. |
| Special Inspection | Engineer | BCC | As required | As advised by Engineer e.g. safety inspections. |
| Maintenance & Repair | On-site Staff | Property Managers | Monthly | Keep drains unblocked and clear of debris likely to restrict flow.<br>Remove any loose concrete in and over public areas. Monitor or repair trip hazards.<br>Make good any minor damage and repair leaks to the drainage system. |

# 8.6 Maintenance Schedule

The maintenance works recommended to be carried out over the next 5 year period (until the next condition survey), along with their priority and estimated cost, are summarised in Table 8.2. It should also be noted that additional maintenance actions may be required after this time, in particular additional concrete repairs. The high value repair and maintenance items are discussed in more detail below.

## 8.6.1 Reinforcement Corrosion

Chloride induced corrosion is the likely mechanism behind the corrosion and spalling noted on the deck tops and is consistent with de-icing salts being brought into the car park by vehicles, as well as possible historic operational use of de-icing salts in the winter.

Although there is currently only minor damage visible, it is certain that corrosion of reinforcement is ongoing and new locations of concrete spalling/ delaminations will continue to occur and this will need to be addressed to maintain the structural integrity, such as a rolling programme of concrete repairs, carried out every 5-10 years depending on the severity/extent and location of damage. A coating system to the deck would also give some benefit in preventing further chloride ingress and reducing the rate of ongoing corrosion. Repairs form a relatively minor proportion of the overall expenditure, at approximately £40,000.

However, given the potential vulnerability of the deck slabs, it is recommended that at a high quality trafficable water-resistant membrane be applied at Ground level, and Levels 1 and 2. Furthermore, consideration should be given to extending the same up to Level 5 inclusive. This represents significant investment of approximately £180,000 to £360,000.

## 8.6.2 Masonry

In general terms, the low level (apron) brickwork is in a reasonable condition but requires minor repairs and local repointing.

As described above, the missing sections of blockwork to the South elevation should be reinstated and consideration given to the installation of the protective cladding system as an alternative. For the present we have just allowed for the repair and treatment of the existing walls.

The cost of replacement cladding of the South elevation with a modern maintenance-free alternative, could be in the range of £95,000 - £115,000, subject to specification. This cost excludes VAT, scaffolding access, professional fees and any potential loss of car park income during the works.

## 8.6.3 Edge protection

The vehicle safety barriers do not comply with current regulations and standards and do not provide adequate protection from a vehicle impact. It is recommended that these barriers are replaced with a suitable system that meet current standards and regulation; this represents a significant proportion of overall costs identified, at approximately £230,000.

## 8.6.4 Stairwell facades

We have allowed for the overhaul of the existing cladding systems but you may find that the cost to replace, in terms of forward maintenance and whole life cycle costing may provide a payback period of up to 10 years if you replace the patent glazing systems.

We would expect the cost of replacement to the patent glazing to be approximately £90,000 for the entrance glazing and doorset and £45,000 for the rear staircase glazing and entrance door.

We have also allowed for local treatment of corroded steelwork and redecoration of all areas, including the stairs. Concrete cladding repairs are shown separately.

## 8.6.5 Summary of Actions

The following actions are compiled and ranked in terms of their priority:

TABLE 8.2
**Summary of Maintenance Actions**

| Item | Priority | Maintenance action | Cost (£) |
|---|---|---|---|
| 1 | High | Investigations to determine the stability and condition of the South elevation infill blockwork masonry walls [no allowance for repairs]. Access cost included. | £7,000 |
| 2 | High | Repair of the southwest elevation infill blockwork masonry walls. Access cost included. | £33,000 |
| 3 | High | Install additional handrailing to stairwells | £5,000 |
| 4 | High | Refurbishment of Staircase A glazing system (entrance elevation) | £19,000 |
| 5 | High | Refurbishment of Staircase B glazing system (rear elevation) | £13,000 |
| 6 | High | Perimeter barriers | £189,364 |
| 7 | High | Internal Barriers | £67,574 |
| 8 | High | Refurbishment of Staircase A concrete cladding (entrance elevation) | £12,000 |
| 9 | High | Refurbishment of Staircase B concrete cladding (rear elevation) | £7,000 |
| 10 | High | Deck concrete repairs | £13,392 |
| 11 | High | Soffit & upstand concrete repairs | £9,730 |
| 12 | High | Elevation concrete repairs | £2,575 |
| 13 | Medium | Replacement of roofing material to staircases and lift core roofs | £4,000 |
| 14 | BCC | Remodelling of entrance for PoF | £50,000 |
| 15 | BCC | Removing existing shutters | £5,000 |
| 16 | BCC | Removing and installing new secure vehicle gate for Contract Parking | £25,000 |
| 17 | BCC | Installing new secure pedestrian gates in stairwells for Contract Parking | £10,000 |
| 18 | Low | Internal redecoration of Staircase A | £6,500 |
| 19 | Low | Internal redecoration of Staircase B | £5,000 |
| 20 | Low | Cost of scaffolding access to Staircase A | £7,000 |
| 21 | Low | Cost of scaffolding access to Staircase B | £5,000 |
| 22 | Low | Cleaning of drainage channels | £500 |
| 23 | Low | Re-painting of drainage pipes | £2,000 |
| 24 | Low | Re-gasketing of drainage pipes | £1,000 |
| 25 | BCC | Aesthetic upgrade of external elevations | - |
| 26 | BCC | Coating and white lining | £465,810 |
| | | **Total** | **£965,445** |

Notes: BCC denotes the action urgency is to be set by BCC. For 10-year operation, all High priority actions should be implemented, plus Items 11 and 16 to 19. For 20-year operation all items should be implemented.

# 8.7 Maintenance options

The maintenance actions in Table 8.2 were reviewed with BCC Parking Services in March 2018.

We understand that BCC have limited funds to undertake works and as such some prioritisation of the works in Table 8.2 is required going forward. The level of expenditure is also in some ways dependent on the future use and life of Temple Gate car park. Part of the uncertainty relates to the future use in relation to the proposed nearby Bristol Arena. Further clarity is expected later in 2018.

The options that BCC might apply are as follows:

Option A: undertaking essential maintenance only, with a view to managing deterioration and predicting end-of useful life within 10-years. This option includes substantial works to the vehicle and pedestrian barriers and the infill walls, and is based on Items 1 through 9 of Table 8.2.

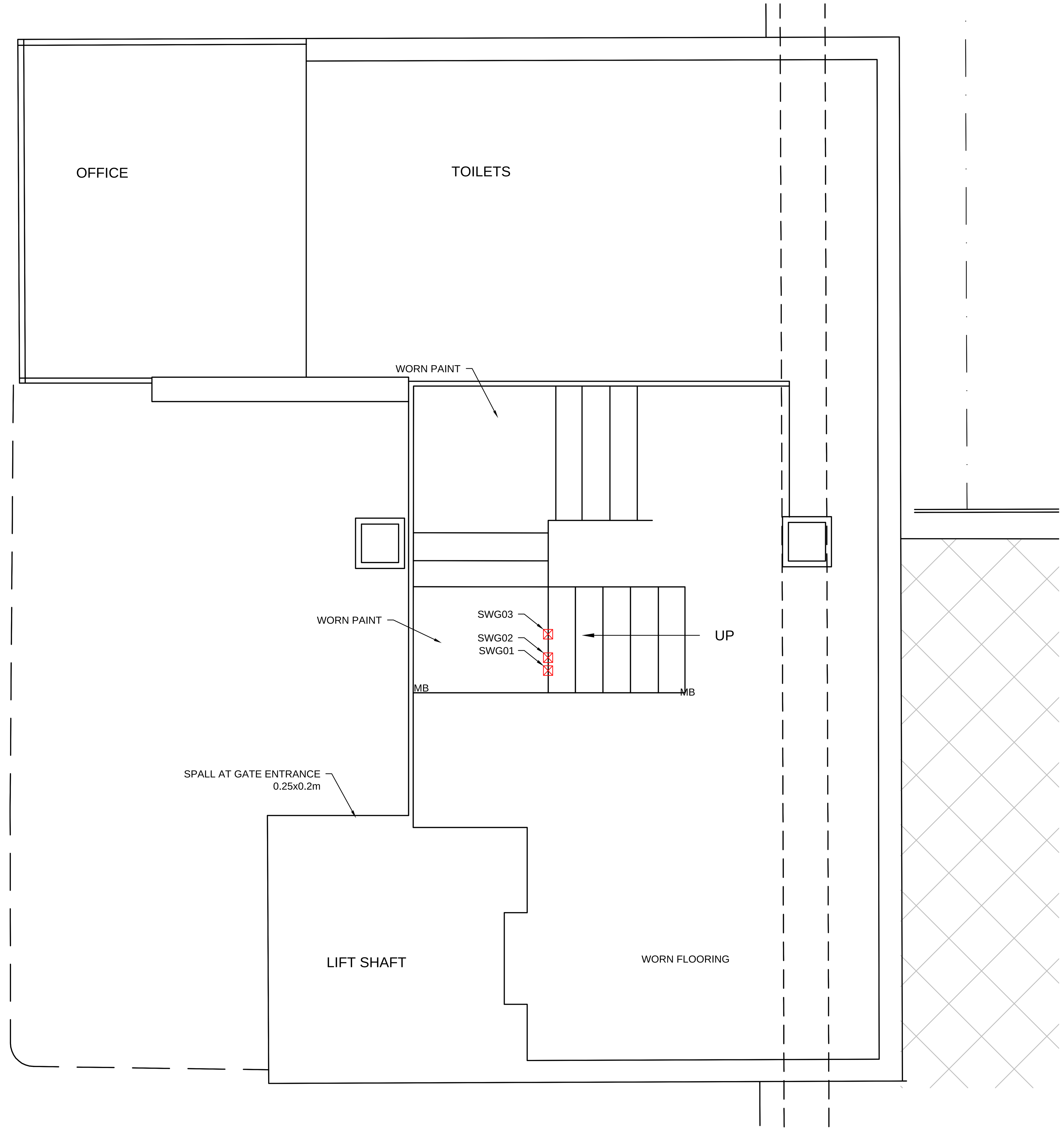
Option B: applying the activities in Option 'A' but also undertaking an elevated level of maintenance, such as patch repairs to decks and soffits, with a view to being able (with further works over time) to more confidently extend life beyond 10-years. The works include line items 1 through 13 of Table 8.2.

Option C: apply most or all actions in Table 8.2 with a view to establishing a further 20-year service life. The main additional actions associated with this option are the application of new water-resistant trafficable coatings to the decks.

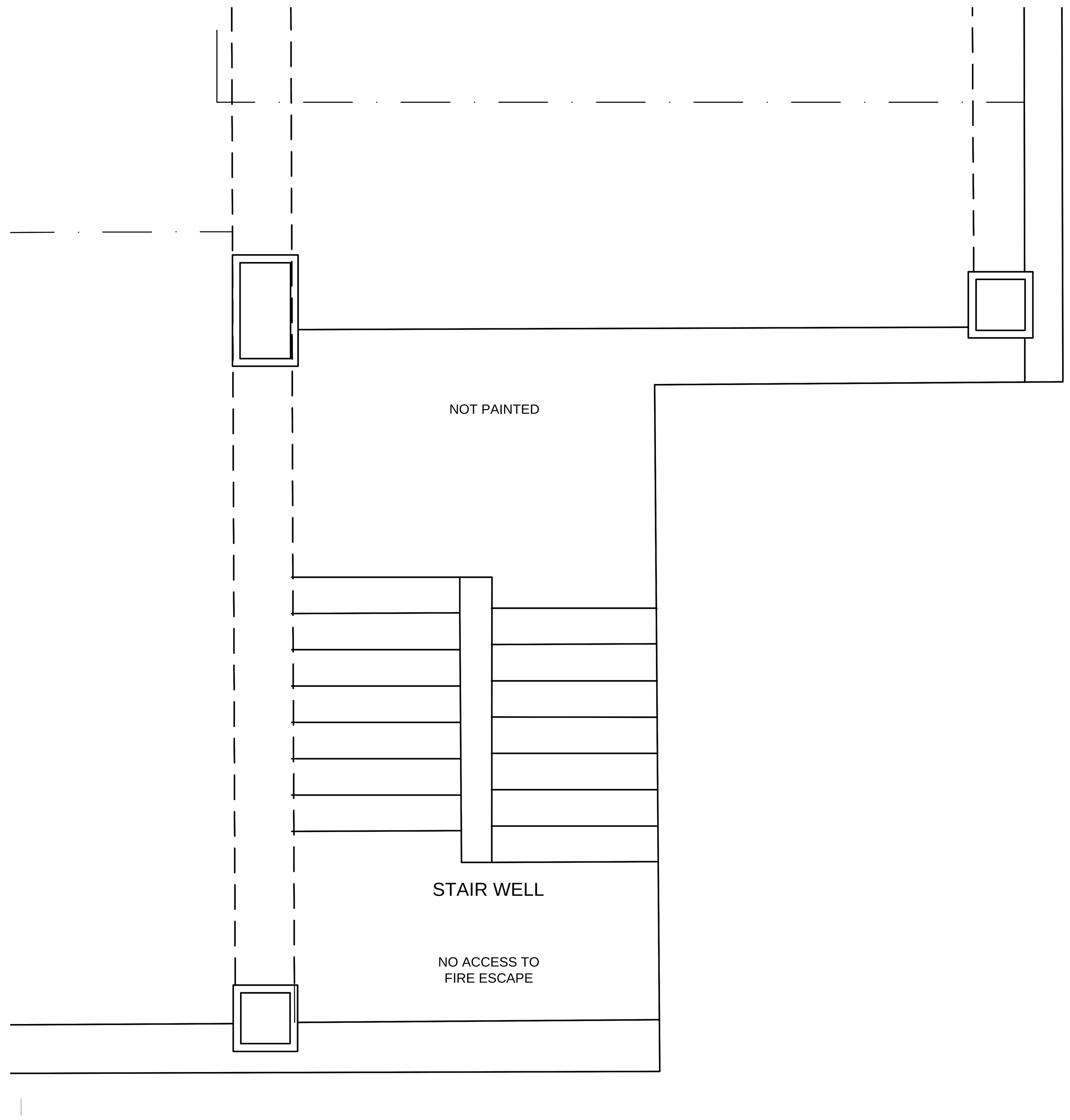
Clearly the maintenance activities and their related costs depend on the option selected. Option A is costed £353,000, whilst Option B is £383,000 where the activities are undertaken at all levels of the car park. We have prepared a spreadsheet '*Temple Gate LCP Optioneering*' which calculates the cost of undertaking the different works for each level within the car park. As condition and usage vary with level, it is possible for BCC to apply a non-uniform approach e.g. not undertaking repair works at high levels, or closing off the highest levels so that expensive barrier works do not need to be undertaken there. In this way, some significant cost savings could be realised.

# Appendix A - Drawings


## GROUND FLOOR PLAN
NOT TO SCALE




## DETAIL 1
NOT TO SCALE




## DETAIL 2
NOT TO SCALE

| CONCRETE REPAIR SCHEDULE - STAIR WELLS | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| SWG01 | 50 | 50 |
| SWG02 | 50 | 50 |
| SWG03 | 50 | 50 |



KEY

MB: MISSING BOLT

☒ STAIR WELL DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE GROUND FLOOR STAIRCASE DEFECTS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

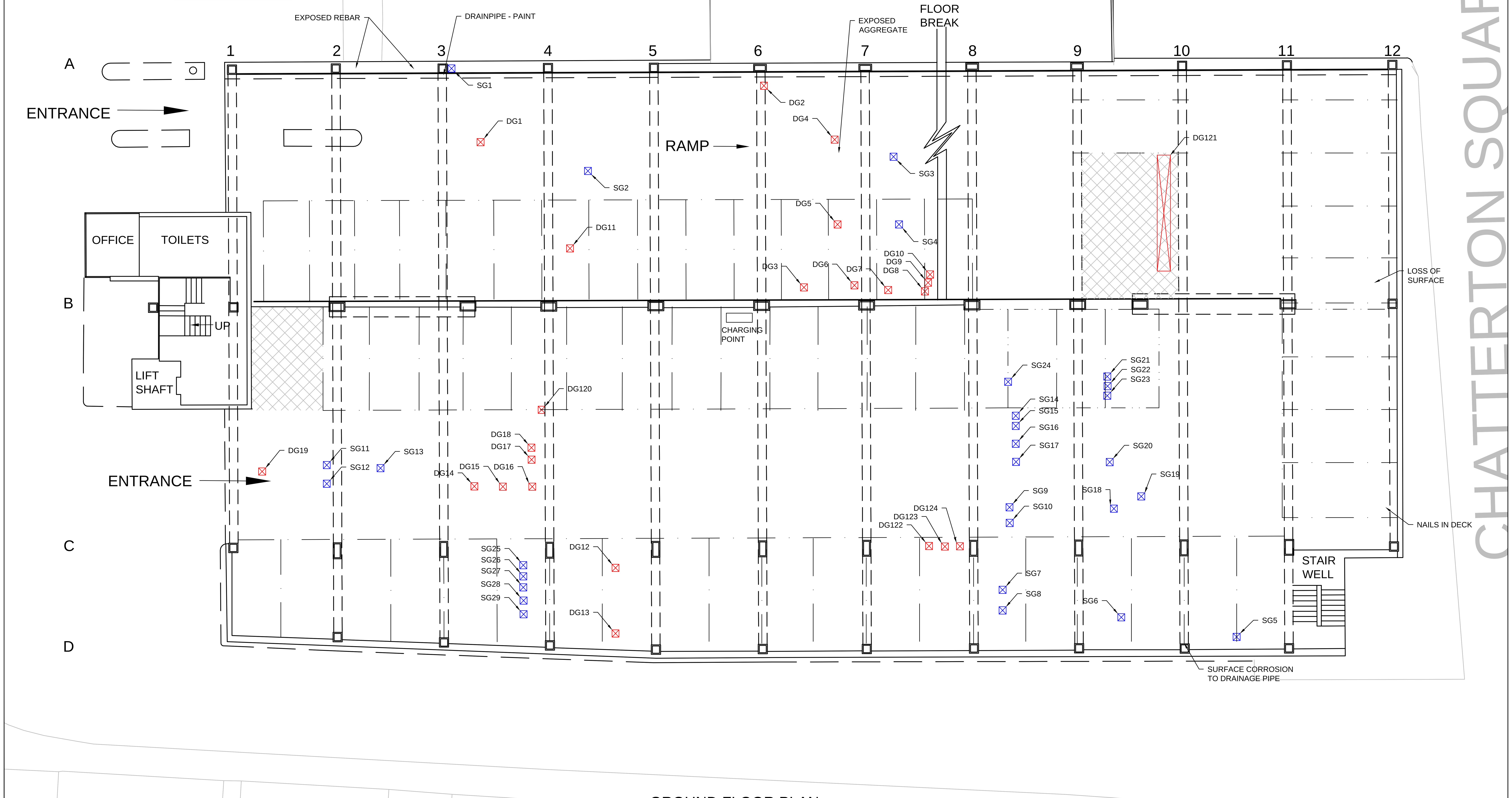
Drawing No. 673846-TG-101

Revision A

Drawing Scale: NTS

| CONCRETE REPAIR SCHEDULE - DECK | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| DG1 | 300 | 300 |
| DG2 | 500 | 150 |
| DG3 | 300 | 200 |
| DG4 | 300 | 300 |
| DG5 | 600 | 600 |
| DG6 | 400 | 300 |
| DG7 | 500 | 500 |
| DG8 | | |
| DG9 | 900 | 550 |
| DG10 | 400 | 600 |
| DG11 | 350 | 350 |
| DG12 | 400 | 150 |
| DG13 | 400 | 100 |
| DG14 | 450 | 250 |
| DG15 | 800 | 300 |
| DG16 | 600 | 400 |
| DG17 | 900 | 200 |
| DG18 | 200 | 100 |
| DG19 | 550 | 300 |
| DG20 | 500 | 550 |
| DG21 | 4720 | 580 |
| DG22 | 200 | 100 |
| DG23 | 500 | 150 |
| DG24 | 100 | 100 |

| CONCRETE REPAIR SCHEDULE - SOFFIT | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| SG1 | 400 | 400 |
| SG2 | 300 | 1200 |
| SG3 | 300 | 500 |
| SG4 | 100 | 500 |
| SG5 | 200 | 200 |
| SG6 | 2300 | 400 |
| SG7 | 100x | 100 |
| SG8 | 300 | 300 |
| SG9 | 200 | 200 |
| SG10 | 200 | 200 |
| SG11 | 400 | 200 |
| SG12 | 200 | 100 |
| SG13 | 100 | 100 |
| SG14 | 300 | 400 |
| SG15 | 300 | 200 |
| SG16 | 100 | 100 |
| SG17 | 100 | 100 |
| SG18 | 700 | 400 |
| SG19 | 600 | 300 |
| SG20 | 400 | 200 |
| SG21 | 100 | 100 |
| SG22 | 200 | 200 |
| SG23 | 200 | 200 |
| SG24 | 600 | 300 |
| SG25 | 300 | 200 |
| SG26 | 200 | 200 |
| SG27 | 150 | 150 |
| SG28 | 150 | 150 |
| SG29 | 200 | 200 |




## GROUND FLOOR PLAN

NOT TO SCALE



## KEY

PPS: PEELING PAINT SOFFIT

- DECK DEFECT
- SOFFIT DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
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ch2m.

Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

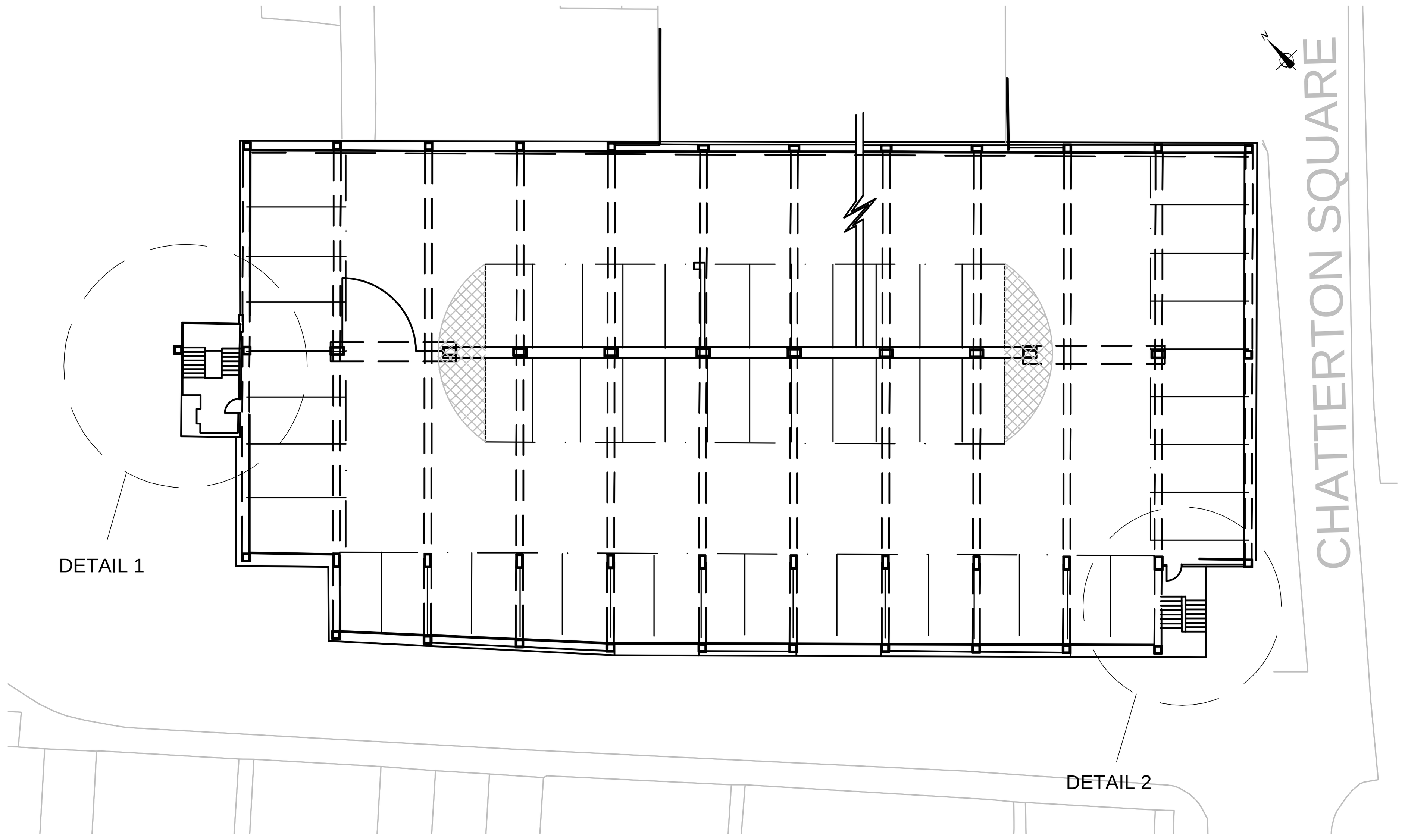
Drawing

TEMPLE GATE GROUND FLOOR DEFECTS

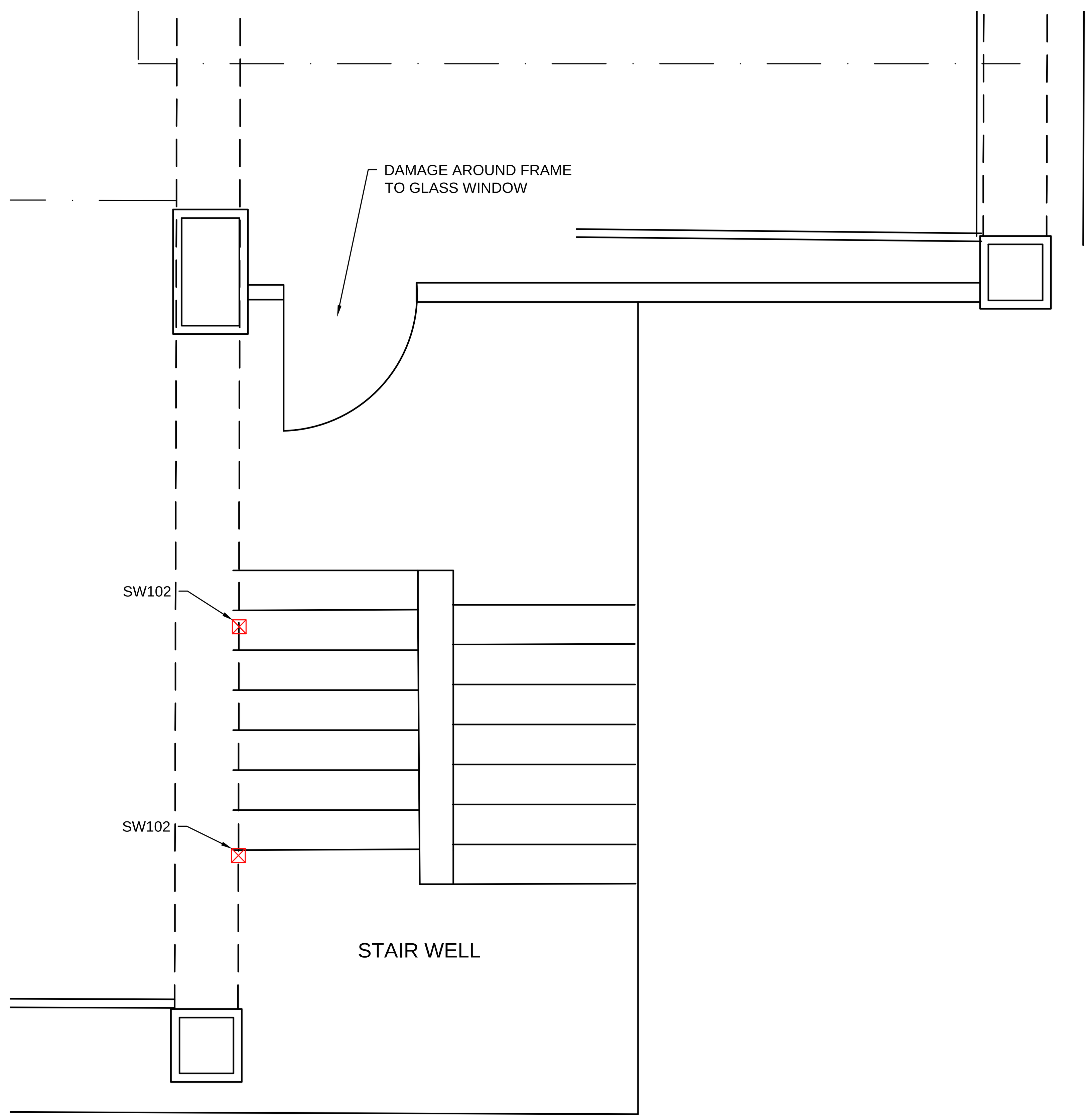
Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-102 Revision A

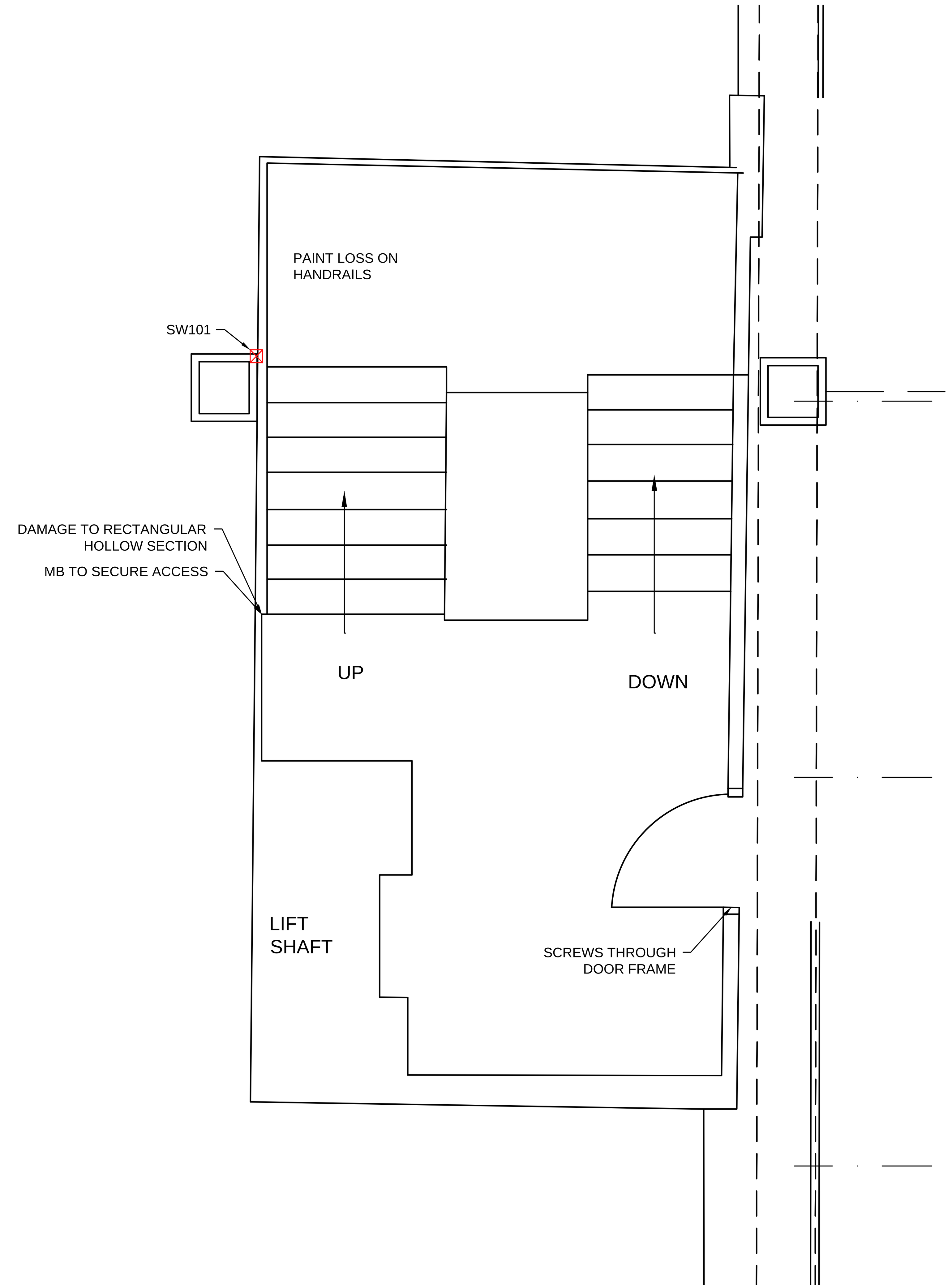
Drawing Scale: NTS




## LEVEL 1 FLOOR PLAN
NOT TO SCALE




## DETAIL 2
NOT TO SCALE




## DETAIL 1
NOT TO SCALE

| CONCRETE REPAIR SCHEDULE - STAIR WELLS | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| SW101 | ? | ? |
| SW102 | 100 | 150 |
| SW103 | 100 | 150 |



## KEY
MB: MISSING BOLT

STAIR WELL DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE
LEVEL 1
STAIRCASE DEFECTS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

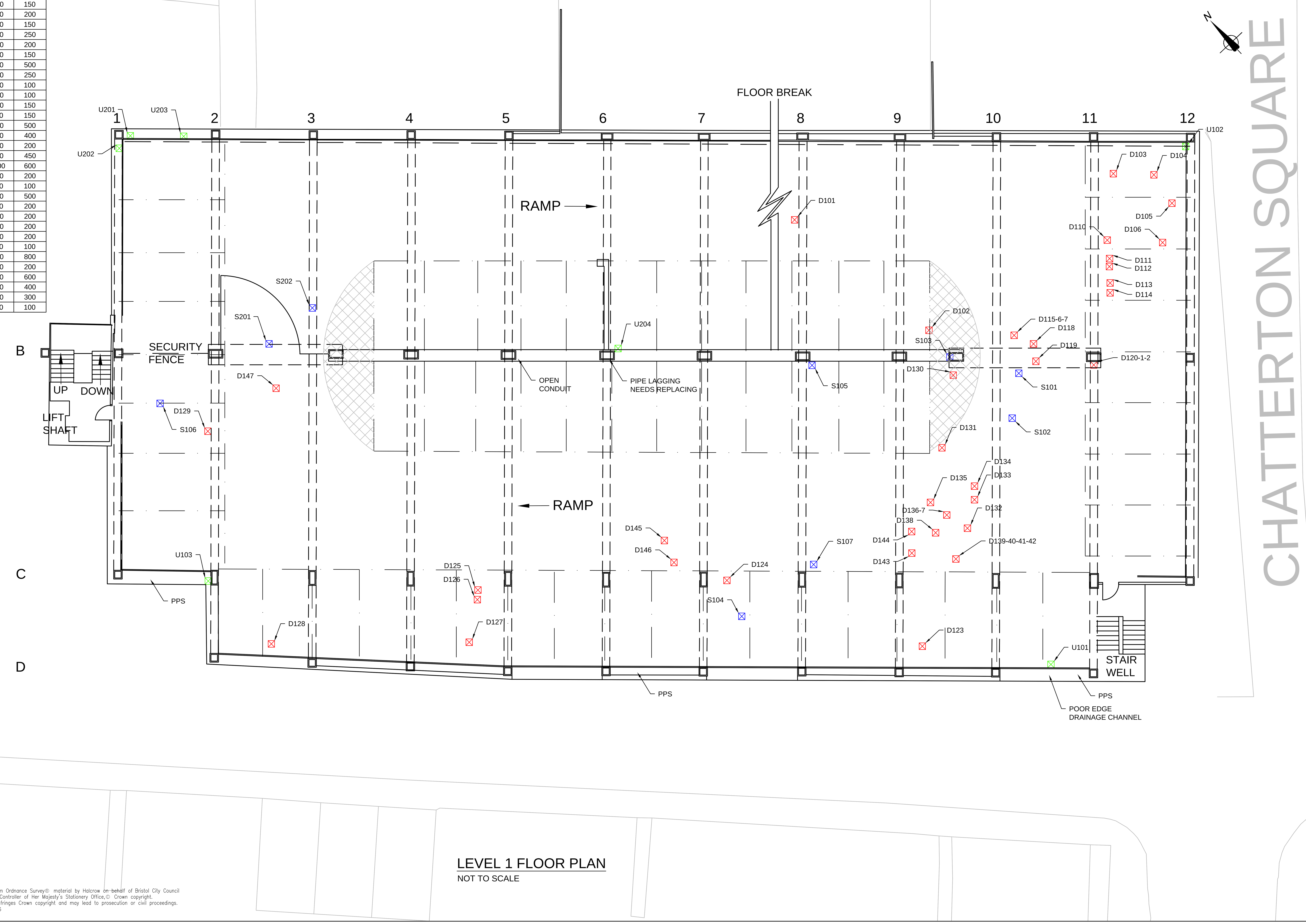
Drawing No. 673846-TG-103
Revision A

Drawing Scale: NTS

| CONCRETE REPAIR SCHEDULE - DECK | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| D101 | 350 | 150 |
| D102 | 750 | 600 |
| D103 | 400 | 400 |
| D104 | 100 | 100 |
| D105 | 200 | 200 |
| D106 | 100 | 400 |
| D107 | 100 | 600 |
| D108 | 100 | 300 |
| D109 | 100 | 500 |
| D110 | 500 | 400 |
| D111 | 900 | 600 |
| D112 | 300 | 200 |
| D113 | 500 | 100 |
| D114 | 500 | 200 |
| D115 | 700 | 250 |
| D116 | 900 | 300 |
| D117 | 400 | 150 |
| D118 | 600 | 200 |
| D119 | 300 | 150 |
| D120 | 300 | 250 |
| D121 | 200 | 200 |
| D122 | 350 | 150 |
| D123 | 750 | 500 |
| D124 | 400 | 250 |
| D125 | 700 | 100 |
| D126 | 250 | 100 |
| D127 | 250 | 150 |
| D128 | 100 | 150 |
| D129 | 400 | 500 |
| D130 | 550 | 400 |
| D131 | 350 | 200 |
| D132 | 550 | 450 |
| D133 | 1000 | 600 |
| D134 | 500 | 200 |
| D135 | 150 | 100 |
| D136 | 500 | 500 |
| D137 | 150 | 200 |
| D138 | 200 | 200 |
| D139 | 450 | 200 |
| D140 | 350 | 200 |
| D141 | 150 | 100 |
| D142 | 400 | 800 |
| D143 | 300 | 200 |
| D144 | 500 | 600 |
| D145 | 600 | 400 |
| D146 | 300 | 300 |
| D147 | 100 | 100 |

| CONCRETE REPAIR SCHEDULE - SOFFIT | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| S101 | 900 | 300 |
| S102 | 100 | 100 |
| S103 | 100 | 100 |
| S104 | 150 | 300 |
| S105 | 100 | 100 |
| S106 | 500 | 400 |
| S107 | 500 | 400 |
| S201 | 100 | 100 |
| S202 | 100 | 100 |

| CONCRETE REPAIR SCHEDULE - UPSTAND | | | |
|---|---|---|---|
| REPAIR REFERENCE | HEIGHT (mm) | LENGTH (mm) | WIDTH (mm) |
| U101 | - | 100 | 100 |
| U102 | 100 | 250 | 150 |
| U103 | 100 | 150 | 300 |
| U201 | 100 | 400 | 150 |
| U202 | 100 | 100 | 100 |
| U203 | - | 500 | 100 |
| U204 | - | 100 | 100 |




## KEY

PPS: PEELING PAINT SOFFIT

- DECK DEFECT
- SOFFIT DEFECT
- UPSTAND DEFECT

## LEVEL 1 FLOOR PLAN

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Client: Bristol City Council

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ch2m

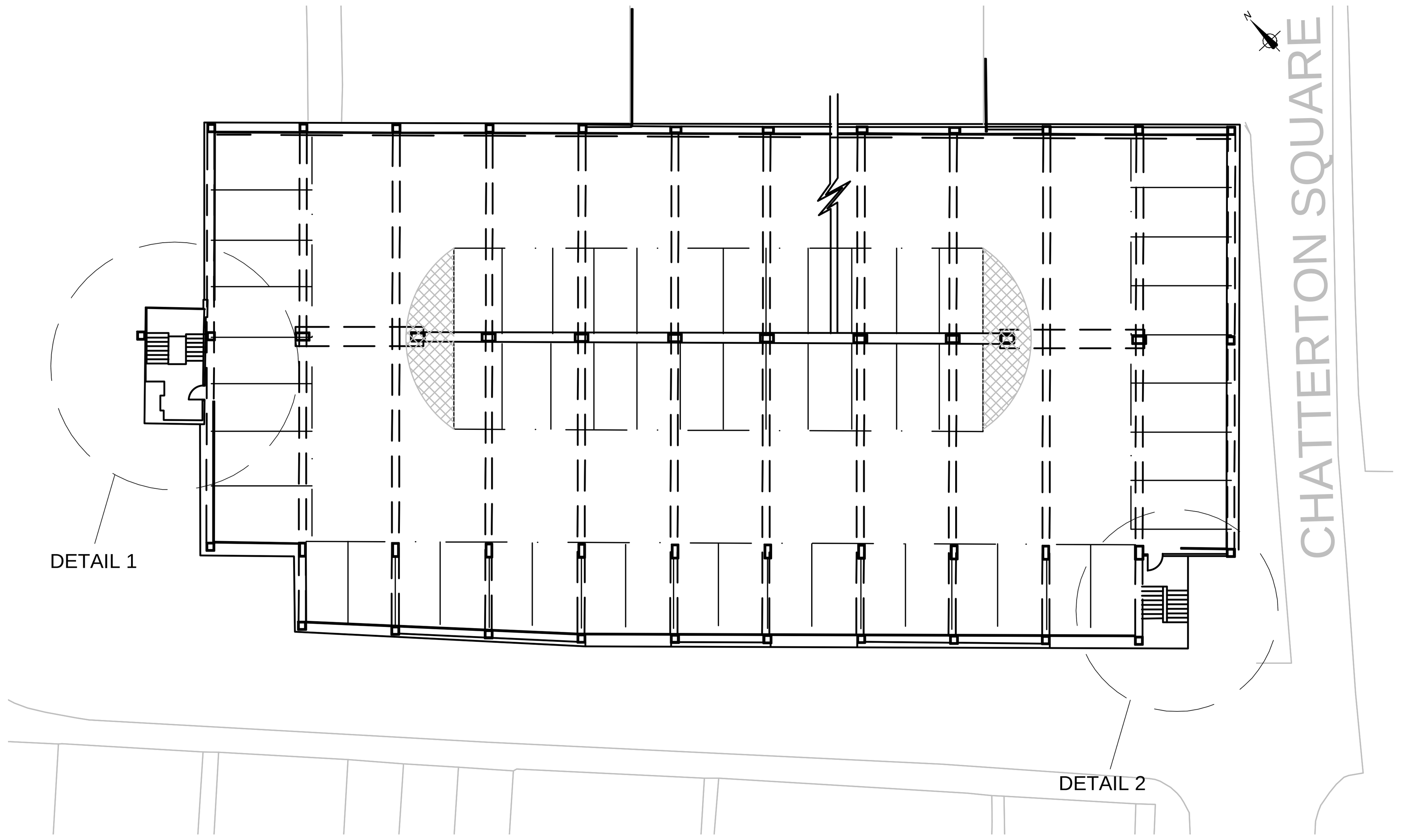
Project: TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing: TEMPLE GATE LEVEL 1 DEFECTS

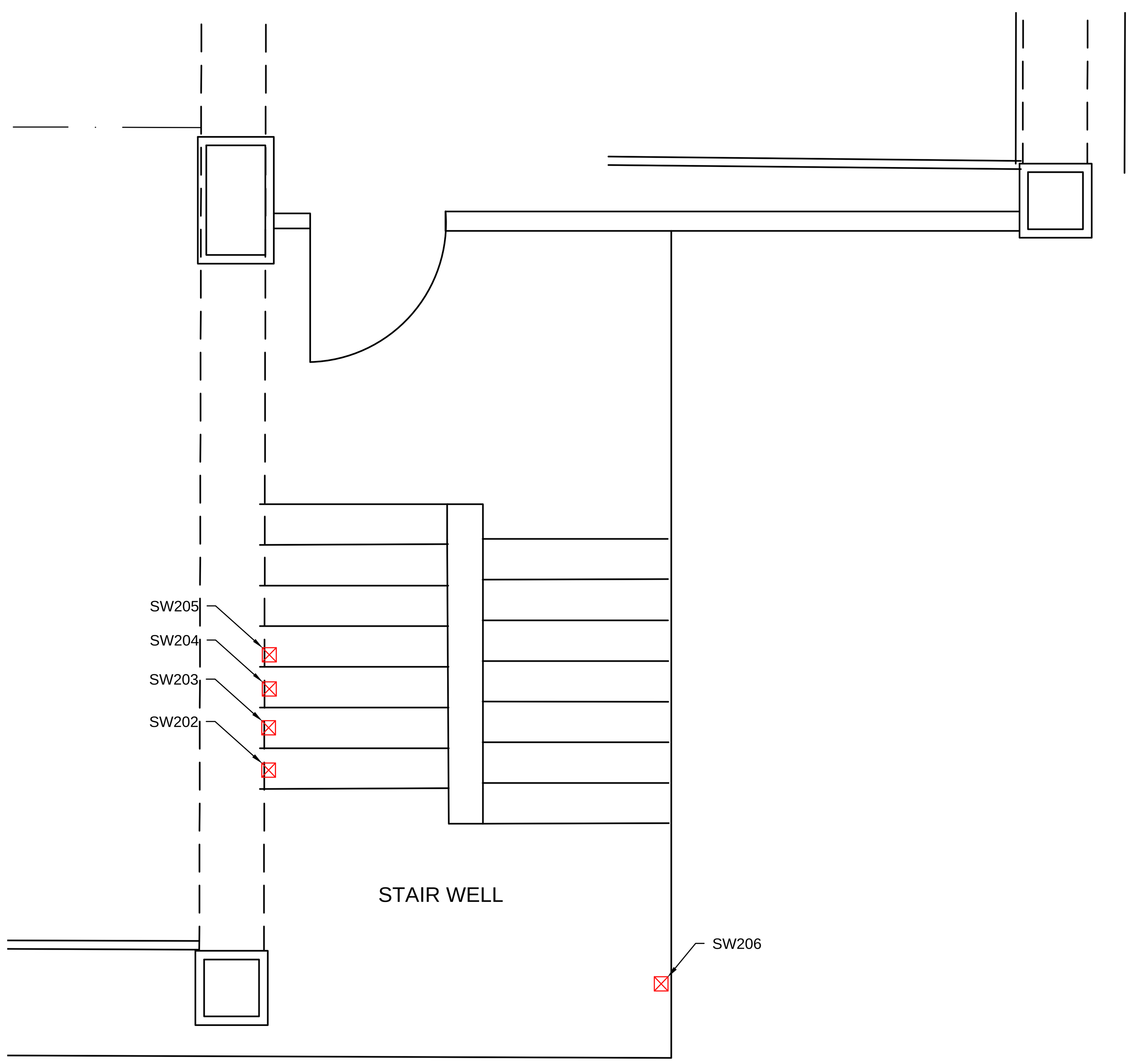
Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No.: 673846-TG-104
Revision: A

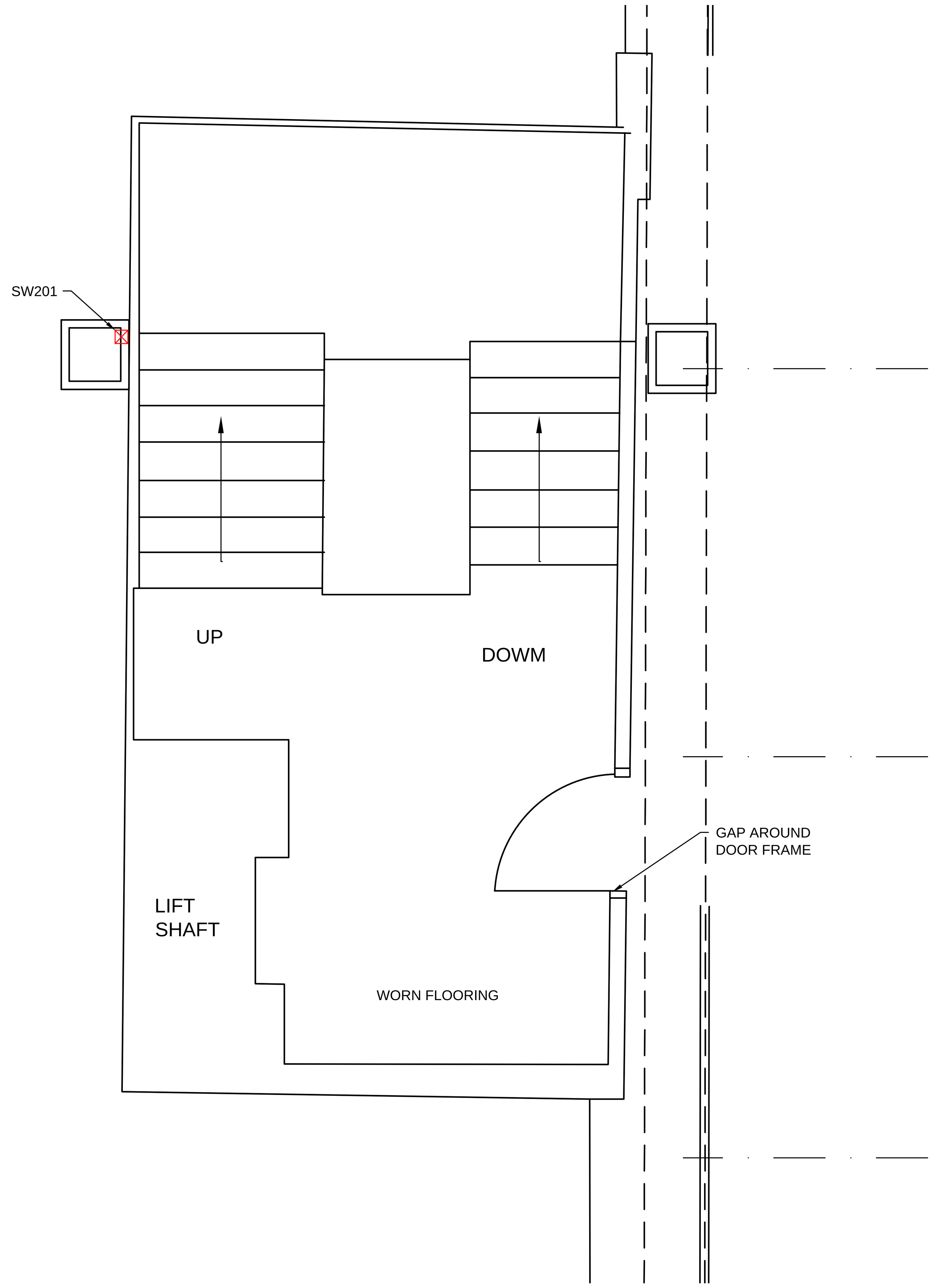
Drawing Scale: NTS




## LEVEL 2 FLOOR PLAN
NOT TO SCALE




## DETAIL 2
NOT TO SCALE




## DETAIL 1
NOT TO SCALE

## KEY
☒ STAIR WELL DEFECT

| CONCRETE REPAIR SCHEDULE - STAIR WELLS | | | |
|---|---|---|---|
| REPAIR REFERENCE | HEIGHT (mm) | LENGTH (mm) | WIDTH (mm) |
| SW201 | - | 200 | 100 |
| SW202 | 250 | 100 | 50 |
| SW203 | 250 | 100 | 50 |
| SW204 | 250 | 100 | 50 |
| SW205 | 250 | 100 | 50 |
| SW206 | - | 400 | 150 |



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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE
LEVEL 2
STAIRCASE DEFECTS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-105
Revision A

Drawing Scale: NTS

| CONCRETE REPAIR SCHEDULE - DECK | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| D201 | 100 | 150 |
| D202 | 500 | 150 |
| D203 | 300 | 400 |
| D204 | 100 | 100 |
| D205 | 200 | 250 |
| D206 | 500 | 250 |
| D207 | 100 | 150 |
| D208 | 700 | 450 |
| D209 | 500 | 300 |
| D210 | 300 | 300 |
| D211 | 300 | 200 |
| D212 | 250 | 350 |
| D301 | 250 | 250 |
| D302 | 200 | 200 |
| D303 | 450 | 500 |
| D304 | 100 | 100 |
| D305 | 500 | 200 |
| D306 | 250 | 200 |
| D307 | 300 | 400 |

| CONCRETE REPAIR SCHEDULE - SOFFIT | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| S203 | 100 | 100 |
| S204 | 200 | 200 |
| S205 | 100 | 200 |
| S206 | 100 | 200 |
| S207 | 100 | 200 |
| S208 | 100 | 100 |
| S209 | 500 | 100 |
| S210 | 100 | 100 |
| S211 | 200 | 300 |
| S212 | 200 | 200 |
| S213 | 200 | 200 |
| S214 | 100 | 100 |
| S215 | 300 | 300 |
| S216 | 300 | 300 |
| S217 | 200 | 100 |
| S218 | 400 | 200 |
| S219 | 200 | 200?? |

| CONCRETE REPAIR SCHEDULE - UPSTAND | | | |
|---|---|---|---|
| REPAIR REFERENCE | HEIGHT (mm) | LENGTH (mm) | WIDTH (mm) |
| U205 | - | 100 | 100 |
| U206 | 100 | 150 | 300 |
| U207 | - | 100 | 200 |
| U208 | - | 100 | 100 |
| U209 | - | 300 | 200 |
| U210 | - | 100 | 100 |
| U211 | - | 100 | 100 |
| U212 | - | 200 | 150 |
| U213 | - | 400 | 200 |
| U214 | - | 100 | 100 |
| U215 | - | 200 | 150 |
| U216 | - | 400 | 100 |
| U217 | - | 350 | 200 |
| U218 | - | 450 | 150 |
| U219 | - | 100 | 100 |
| U220 | - | 100 | 100 |
| U301 | 100 | 300 | 100 |
| U302 | 100 | 200 | 150 |


## LEVEL 2 FLOOR PLAN

NOT TO SCALE



## KEY

- DECK DEFECT
- SOFFIT DEFECT
- UPSTAND DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

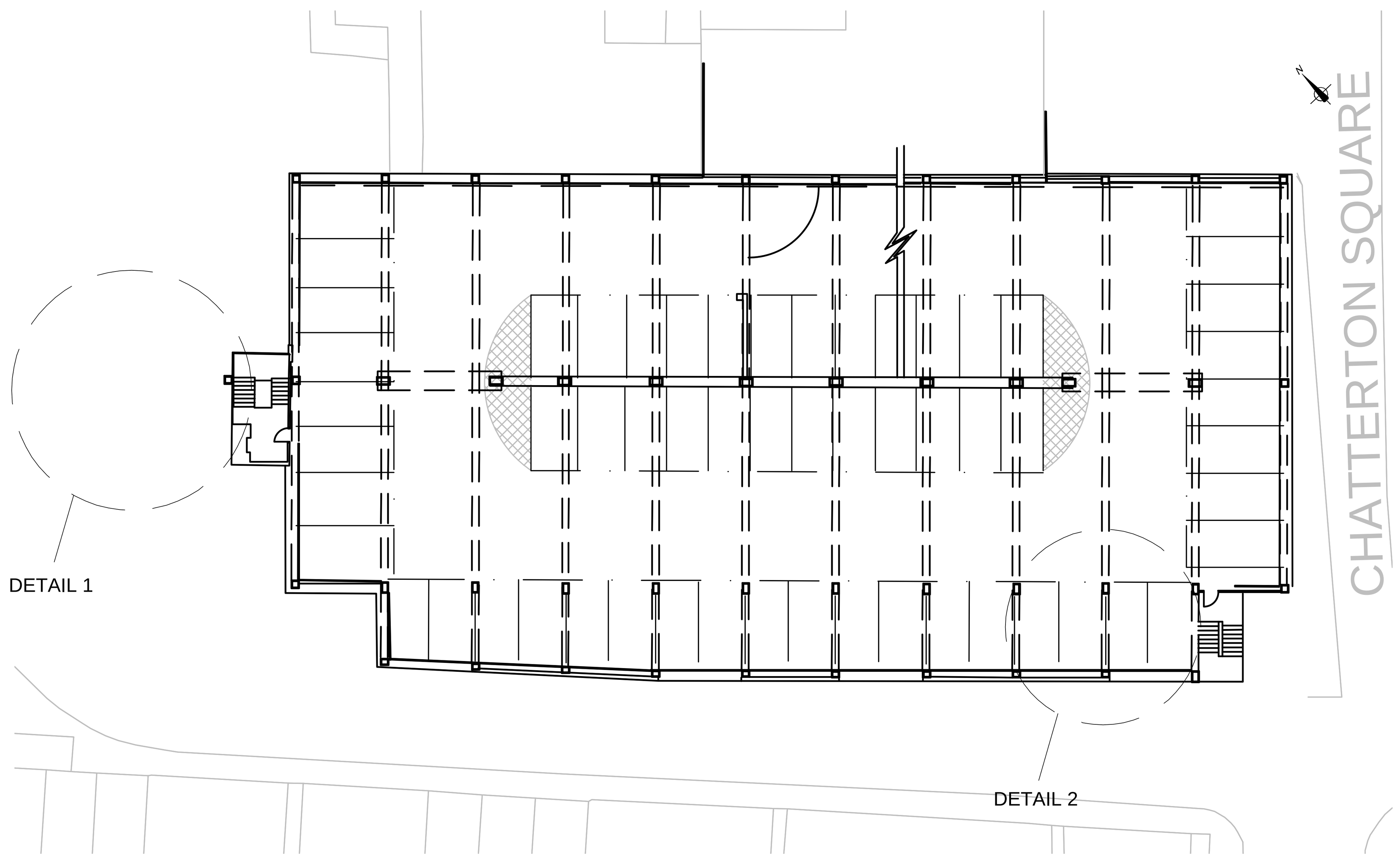
Drawing

TEMPLE GATE LEVEL 2 DEFECTS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

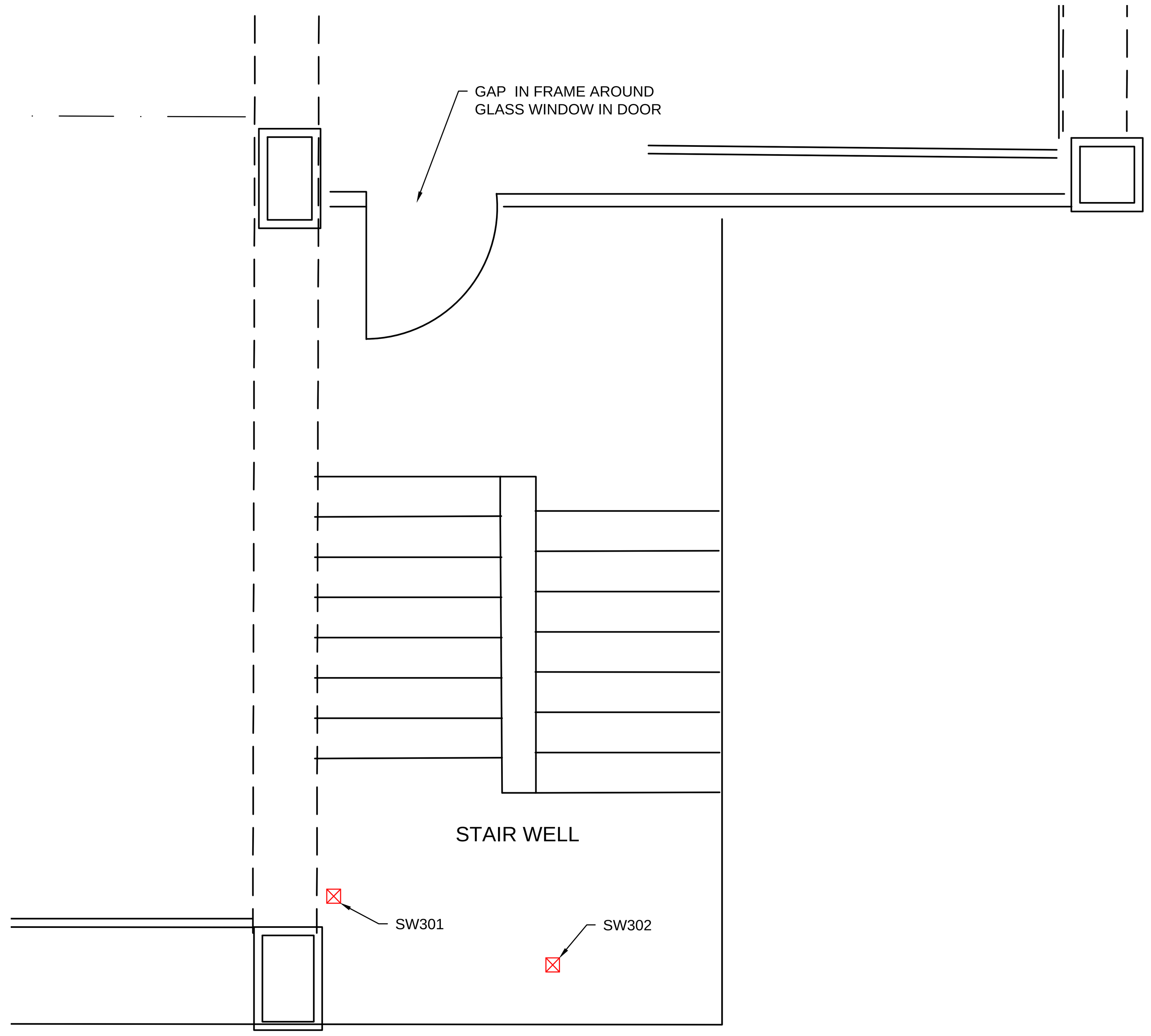
Drawing No. 673846-TG-106 Revision A

Drawing Scale: NTS



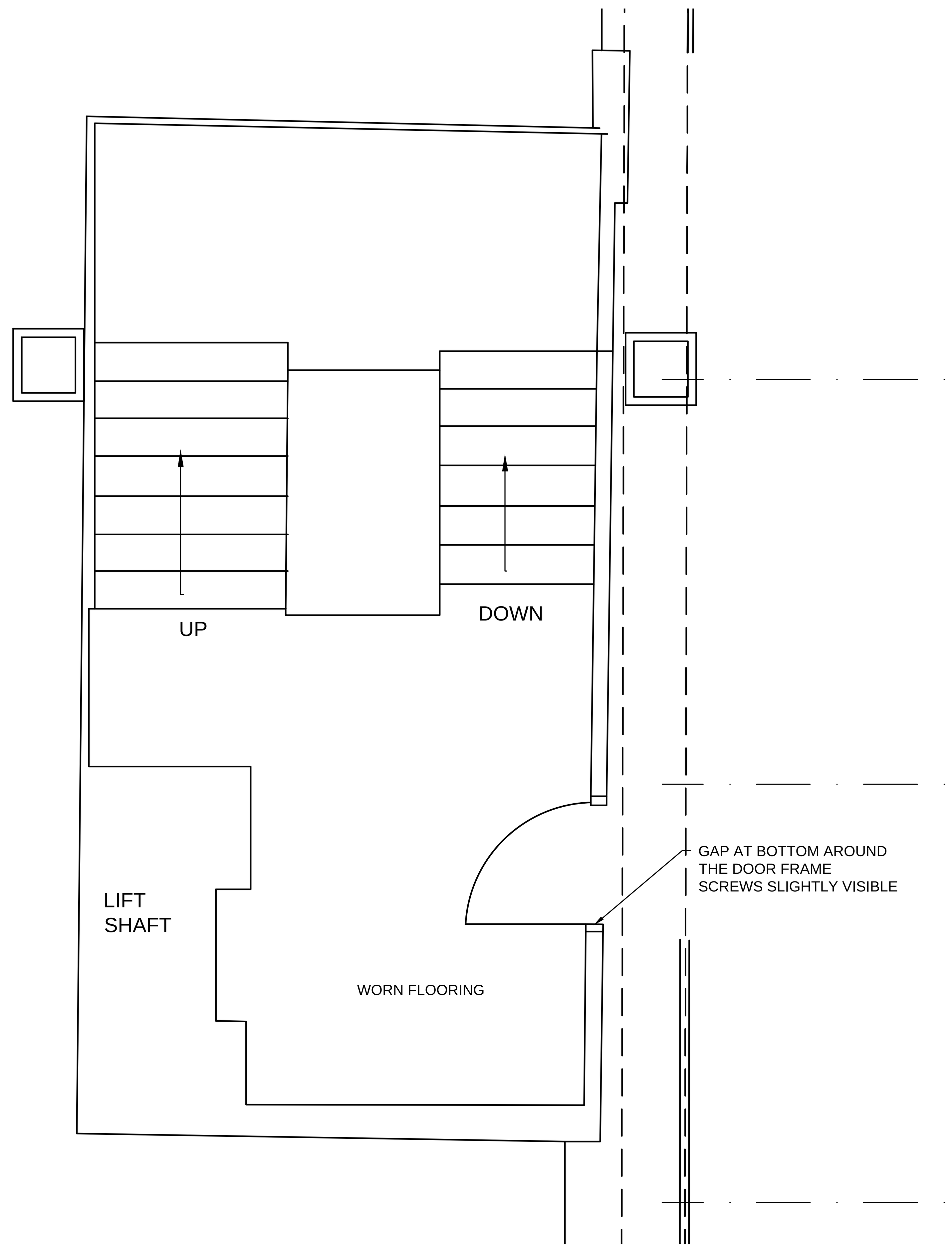

LEVEL 3 FLOOR PLAN

NOT TO SCALE




DETAIL 2

NOT TO SCALE




DETAIL 1

NOT TO SCALE

| CONCRETE REPAIR SCHEDULE - STAIR WELLS | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| SW301 | 300 | 250 |
| SW302 | 300 | 200 |

KEY

⊠ STAIR WELL DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE
LEVEL 3
STAIRCASE DEFECTS

Drawn by: FG Date: 13/02/2018

Checked by: AP Date: 13/02/2018

Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-107

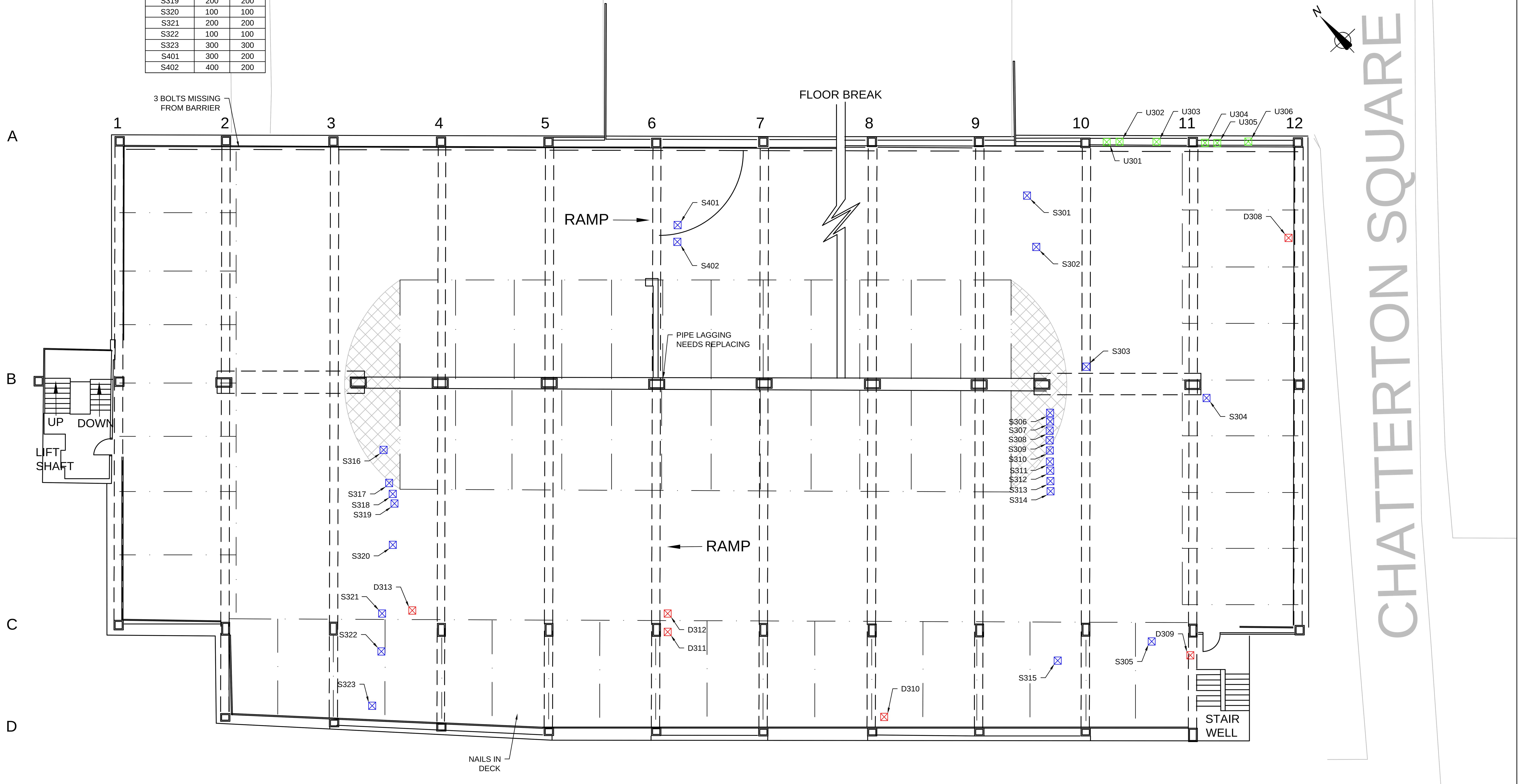
Revision A

Drawing Scale: NTS

| CONCRETE REPAIR SCHEDULE - DECK | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| D308 | 500 | 350 |
| D309 | 200 | 100 |
| D310 | 200 | 200 |
| D311 | 250 | 150 |
| D312 | 450 | 100 |
| D313 | 100 | 100 |

| CONCRETE REPAIR SCHEDULE - SOFFIT | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| S301 | 200 | 200 |
| S302 | 200 | 200 |
| S303 | 200 | 100 |
| S304 | 200 | 200 |
| S305 | 200 | 200 |
| S306 | 200 | 100 |
| S307 | 400 | 100 |
| S308 | 400 | 100 |
| S309 | 200 | 200 |
| S310 | 200 | 100??? |
| S311 | 150 | 100 |
| S312 | 300 | 300 |
| S313 | 500 | 700 |
| S314 | 500 | 300 |
| S315 | 1000 | 400 |
| S316 | 400 | 200 |
| S317 | 300 | 200 |
| S318 | 300 | 200 |
| S319 | 200 | 200 |
| S320 | 100 | 100 |
| S321 | 200 | 200 |
| S322 | 100 | 100 |
| S323 | 300 | 300 |
| S401 | 300 | 200 |
| S402 | 400 | 200 |

| CONCRETE REPAIR SCHEDULE - UPSTAND | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| U301 | 200 | 100 |
| U302 | 100 | 100 |
| U303 | 200 | 200 |
| U304 | 300 | 100 |
| U305 | 100 | 100 |
| U306 | 200 | 200 |




## LEVEL 3 FLOOR PLAN

NOT TO SCALE



## KEY

- DECK DEFECT
- SOFFIT DEFECT
- UPSTAND DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client

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ch2m

Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

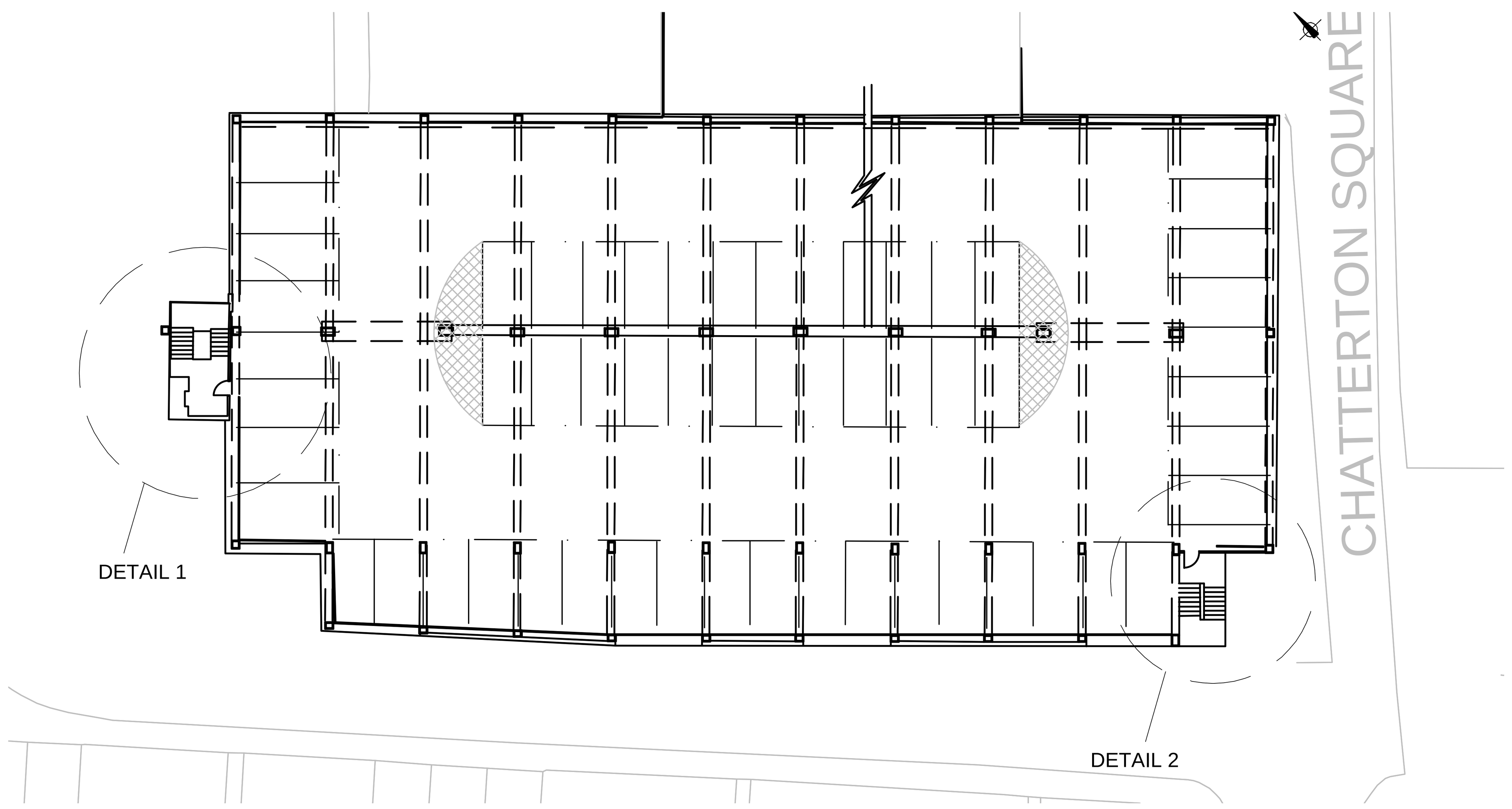
Drawing

TEMPLE GATE LEVEL 3 DEFECTS

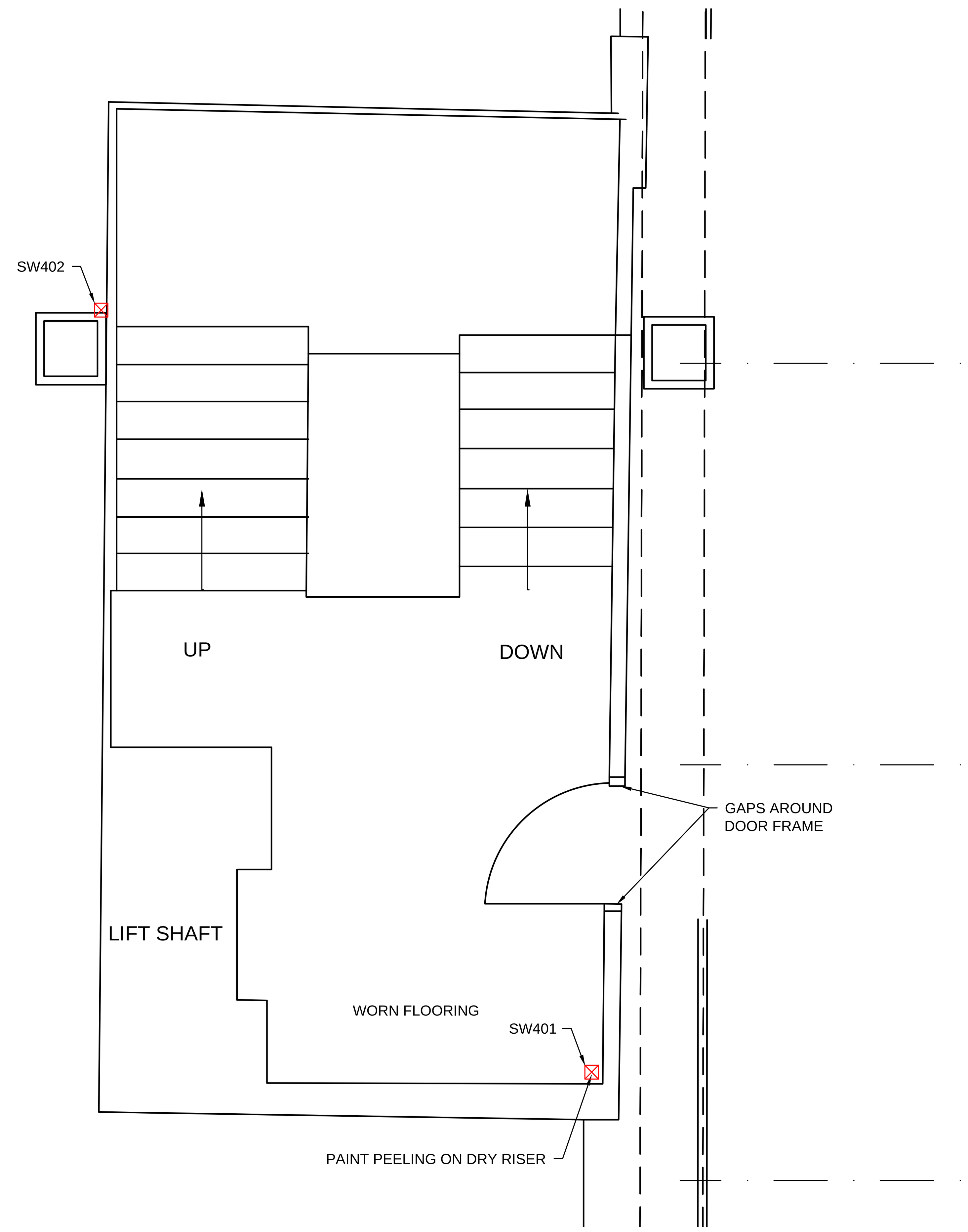
Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-108 Revision A

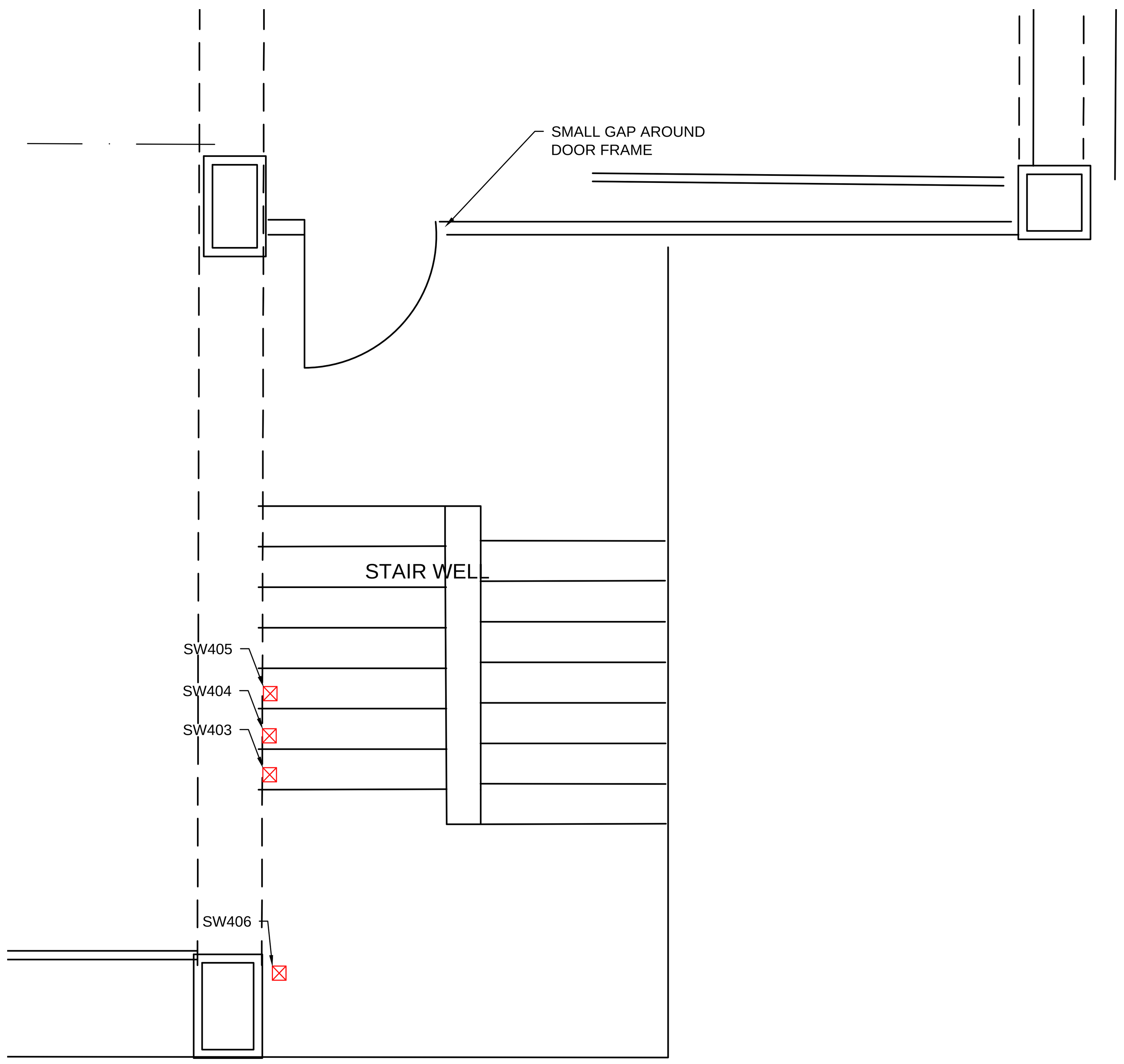
Drawing Scale: NTS




LEVEL 4 FLOOR PLAN
NOT TO SCALE




DETAIL 1
NOT TO SCALE




DETAIL 2
NOT TO SCALE

| CONCRETE REPAIR SCHEDULE - STAIR WELLS | | | |
|---|---|---|---|
| REPAIR REFERENCE | HEIGHT (mm) | LENGTH (mm) | WIDTH (mm) |
| SW301 | - | 500 | 300 |
| SW302 | 500 | 150 | 100 |
| SW303 | 250 | 150 | 50 |
| SW304 | 250 | 150 | 50 |
| SW305 | 250 | 150 | 50 |
| SW306 | - | 150 | 150 |



## KEY

☒ STAIR WELL DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client

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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE
LEVEL 4
STAIRCASE DEFECTS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-109
Revision A

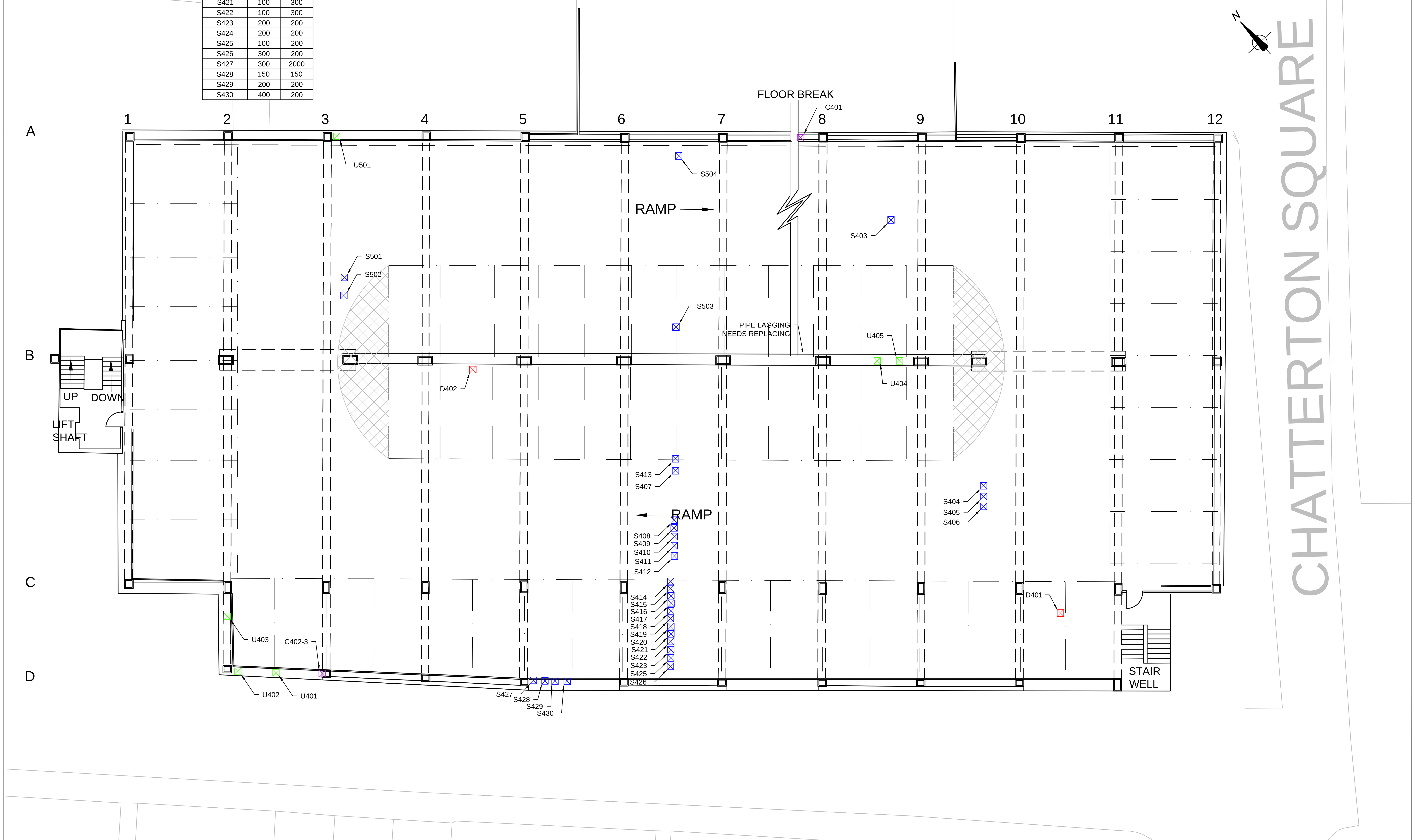
Drawing Scale: NTS

| CONCRETE REPAIR SCHEDULE - DECK | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| D401 | 200 | 200 |
| D402 | 200 | 100 |

| CONCRETE REPAIR SCHEDULE - SOFFIT | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| S403 | 100 | 100 |
| S404 | 400 | 200 |
| S405 | 300 | 200 |
| S406 | 300 | 300 |
| S407 | 500 | 200 |
| S408 | 200 | 200 |
| S409 | 200 | 200 |
| S410 | 100 | 100 |
| S411 | 100 | 150 |
| S412 | 200 | 200 |
| S413 | 100 | 100 |
| S414 | 100 | 100 |
| S415 | 100 | 100 |
| S416 | 100 | 100 |
| S417 | 300 | 100 |
| S418 | 100 | 100 |
| S419 | 100 | 150 |
| S420 | 600 | 300 |
| S421 | 100 | 300 |
| S422 | 100 | 300 |
| S423 | 200 | 200 |
| S424 | 200 | 200 |
| S425 | 100 | 200 |
| S426 | 300 | 200 |
| S427 | 300 | 2000 |
| S428 | 150 | 150 |
| S429 | 200 | 200 |
| S430 | 400 | 200 |

| CONCRETE REPAIR SCHEDULE - UPSTAND | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| U401 | 100 | 100 |
| U402 | 100 | 100 |
| U403 | 100 | 100 |
| U404 | 150 | 100 |
| U405 | 100 | 50 |

| CONCRETE REPAIR SCHEDULE - COLUMN | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| C401 | 250 | 250 |
| C402 | 200 | 100 |
| C403 | 100 | 100 |




## LEVEL 4 FLOOR PLAN

NOT TO SCALE



## KEY

- DECK DEFECT
- SOFFIT DEFECT
- UPSTAND DEFECT
- COLUMN DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client

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ch2m

Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

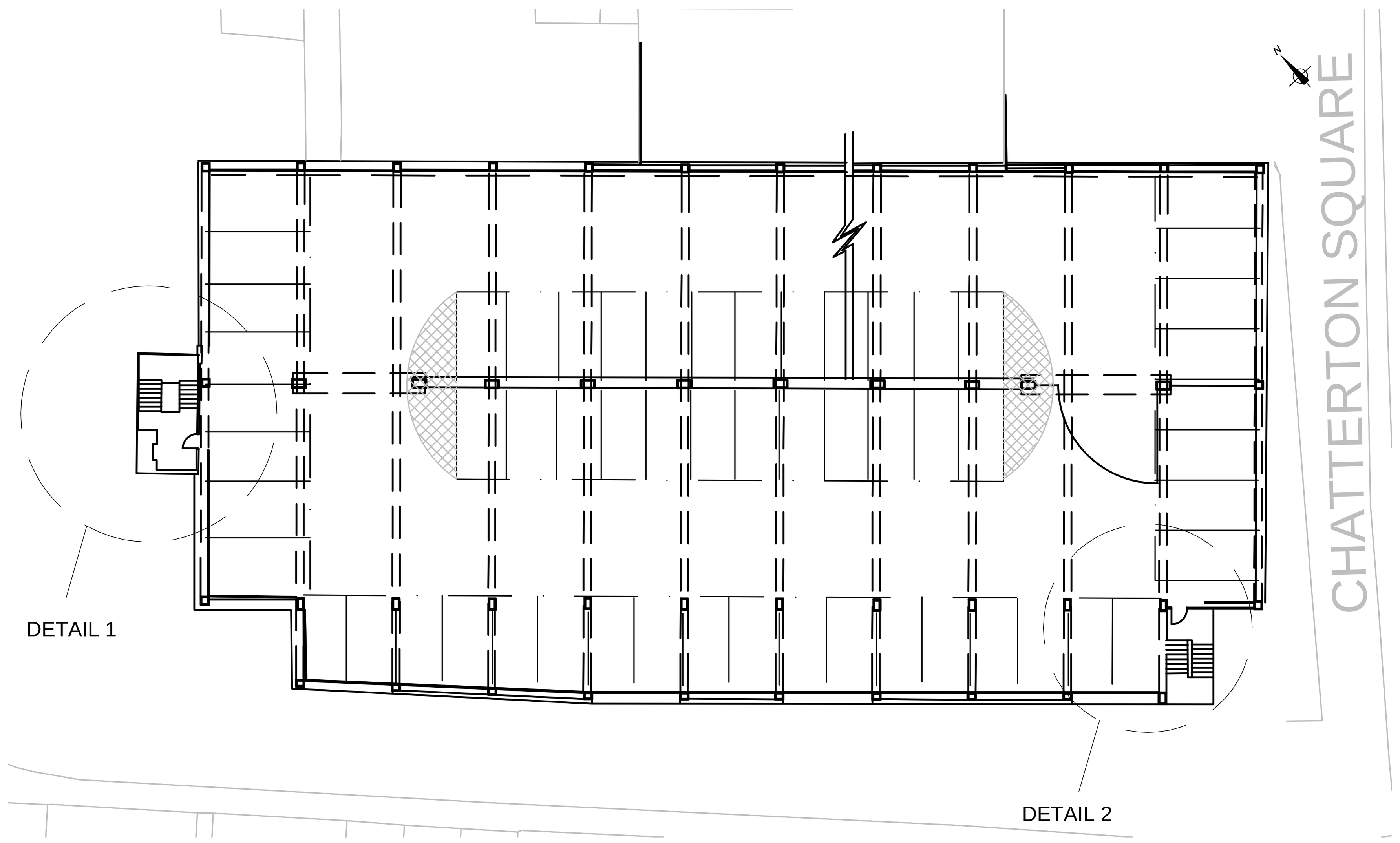
TEMPLE GATE LEVEL 4 DEFECTS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

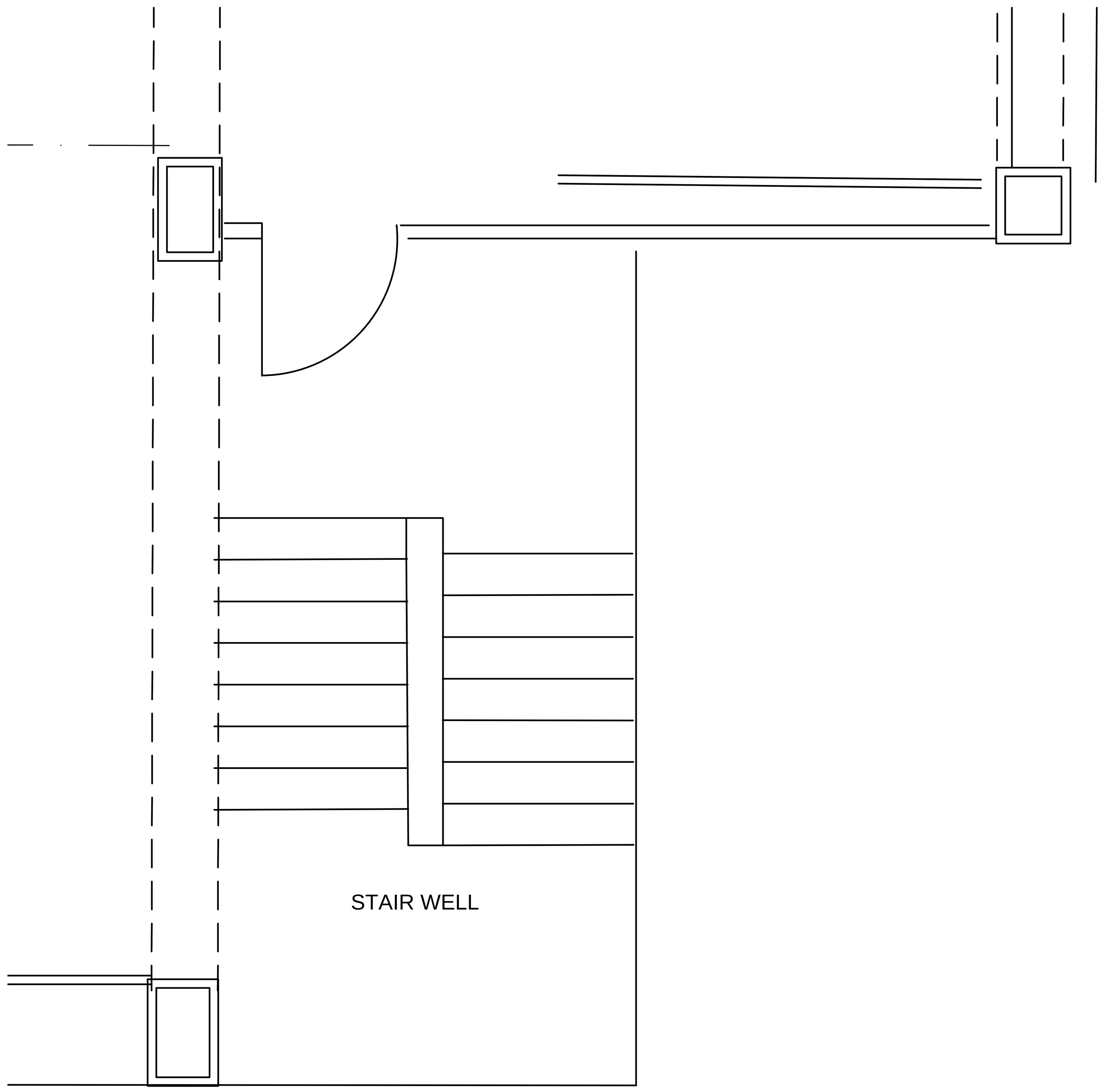
Drawing No. 673846-TG-110

Revision A

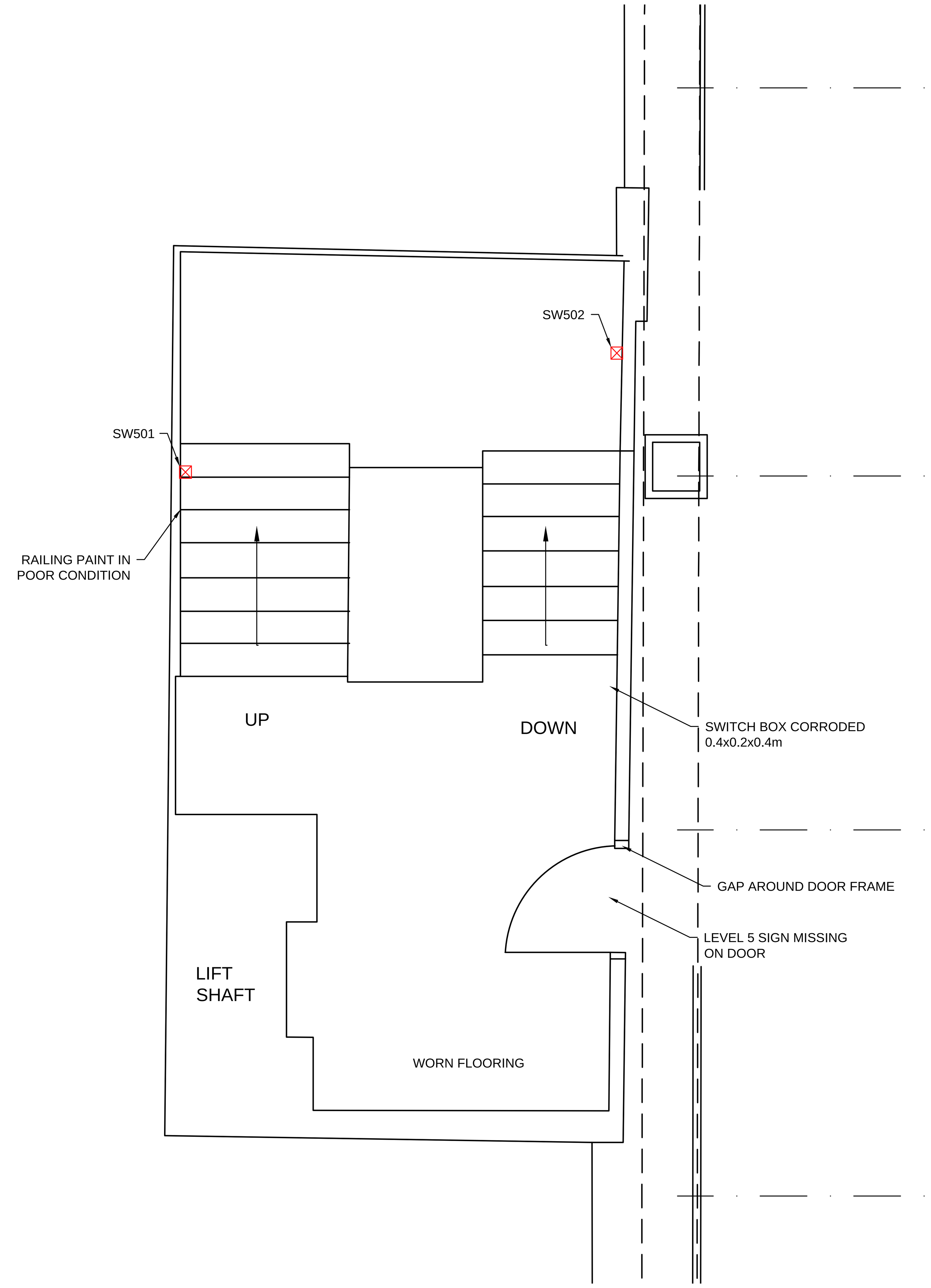
Drawing Scale: NTS




LEVEL 5 FLOOR PLAN
NOT TO SCALE




DETAIL 2
NOT TO SCALE




DETAIL 1
NOT TO SCALE

| CONCRETE REPAIR SCHEDULE - STAIR WELLS | | | |
|---|---|---|---|
| REPAIR REFERENCE | HEIGHT (mm) | LENGTH (mm) | WIDTH (mm) |
| SW501 | 100 | 100 | 100 |
| SW502 | - | 100 | 100 |



KEY

☒ STAIR WELL DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client

Bristol City Council

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ch2m

Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE
LEVEL 5
STAIRCASE DEFECTS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-111

Revision A

Drawing Scale: NTS

| CONCRETE REPAIR SCHEDULE - DECK | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| D501 | 100 | 100 |
| D502 | 100 | 100 |
| D503 | 100 | 100 |
| D504 | 500 | 200 |
| D505 | 300 | 400 |
| D506 | 900 | 200 |
| D507 | 150 | 100 |
| D508 | | |
| D509 | | |
| D510 | 200 | 500 |
| D511 | 150 | 150 |
| D512 | 150 | 250 |
| D513 | 100 | 100 |
| D514 | 500 | 200 |

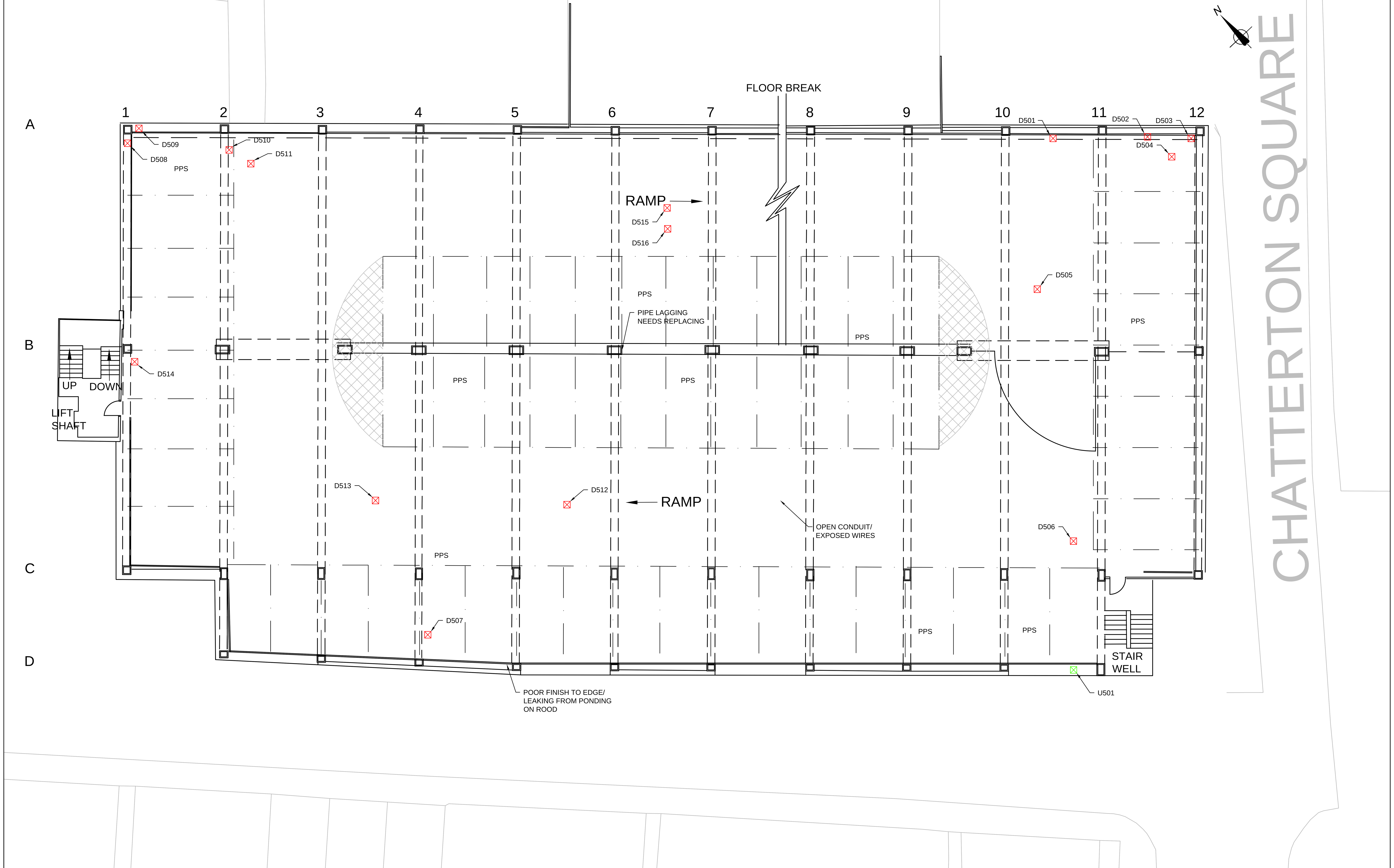
| CONCRETE REPAIR SCHEDULE - UPSTAND | | | |
|---|---|---|---|
| REPAIR REFERENCE | HEIGHT (mm) | LENGTH (mm) | WIDTH (mm) |
| U501 | 100 | 100 | 300 |

KEY

PPS: PEELING PAINT SOFFIT

DECK DEFECT

UPSTAND DEFECT




## LEVEL 5 FLOOR PLAN

NOT TO SCALE



| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client

**CH2M HILL**
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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE LEVEL 5 DEFECTS

Drawn by: FG Date: 13/02/2018

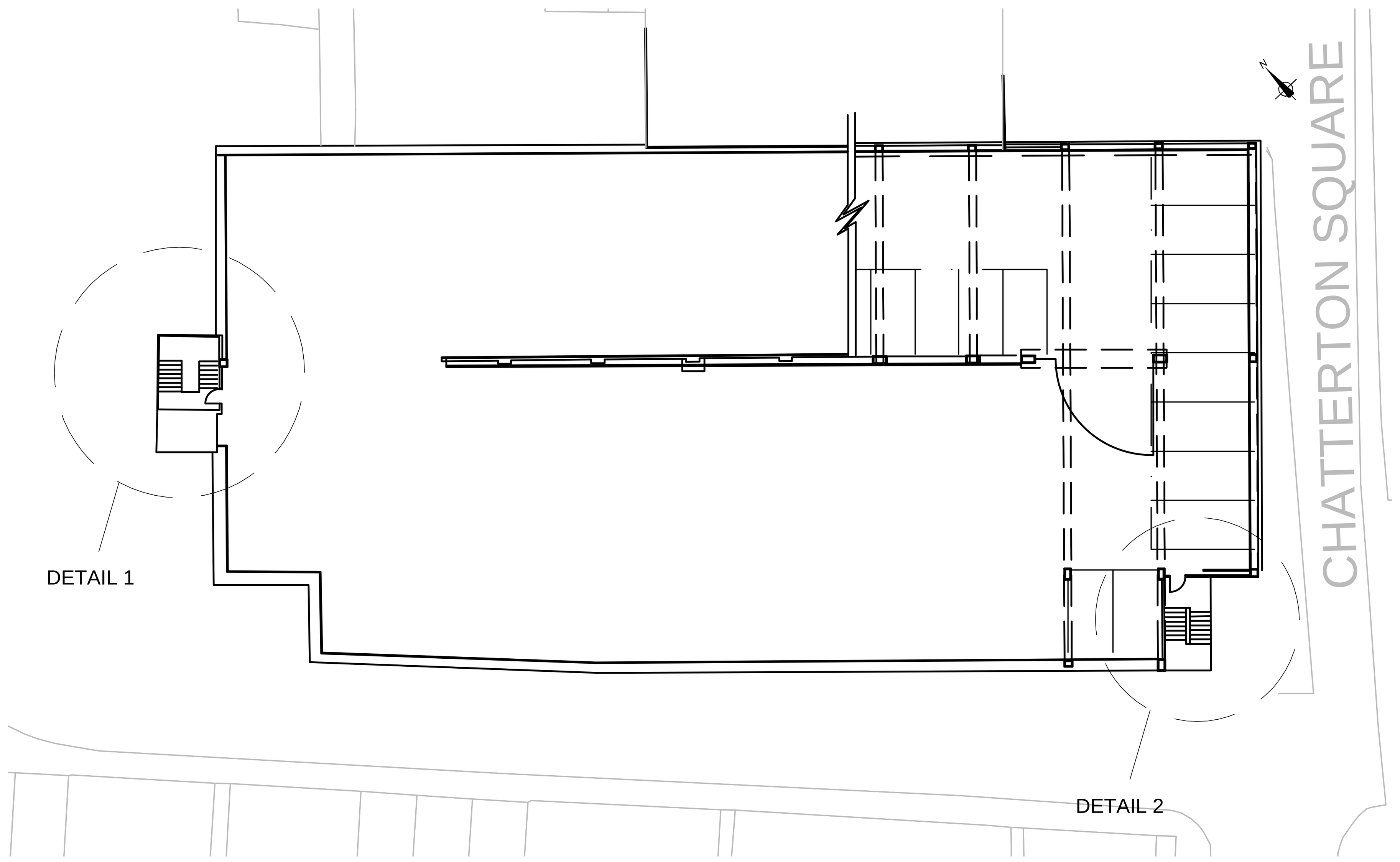
Checked by: AP Date: 13/02/2018

Approved by: RB Date: 13/02/2018

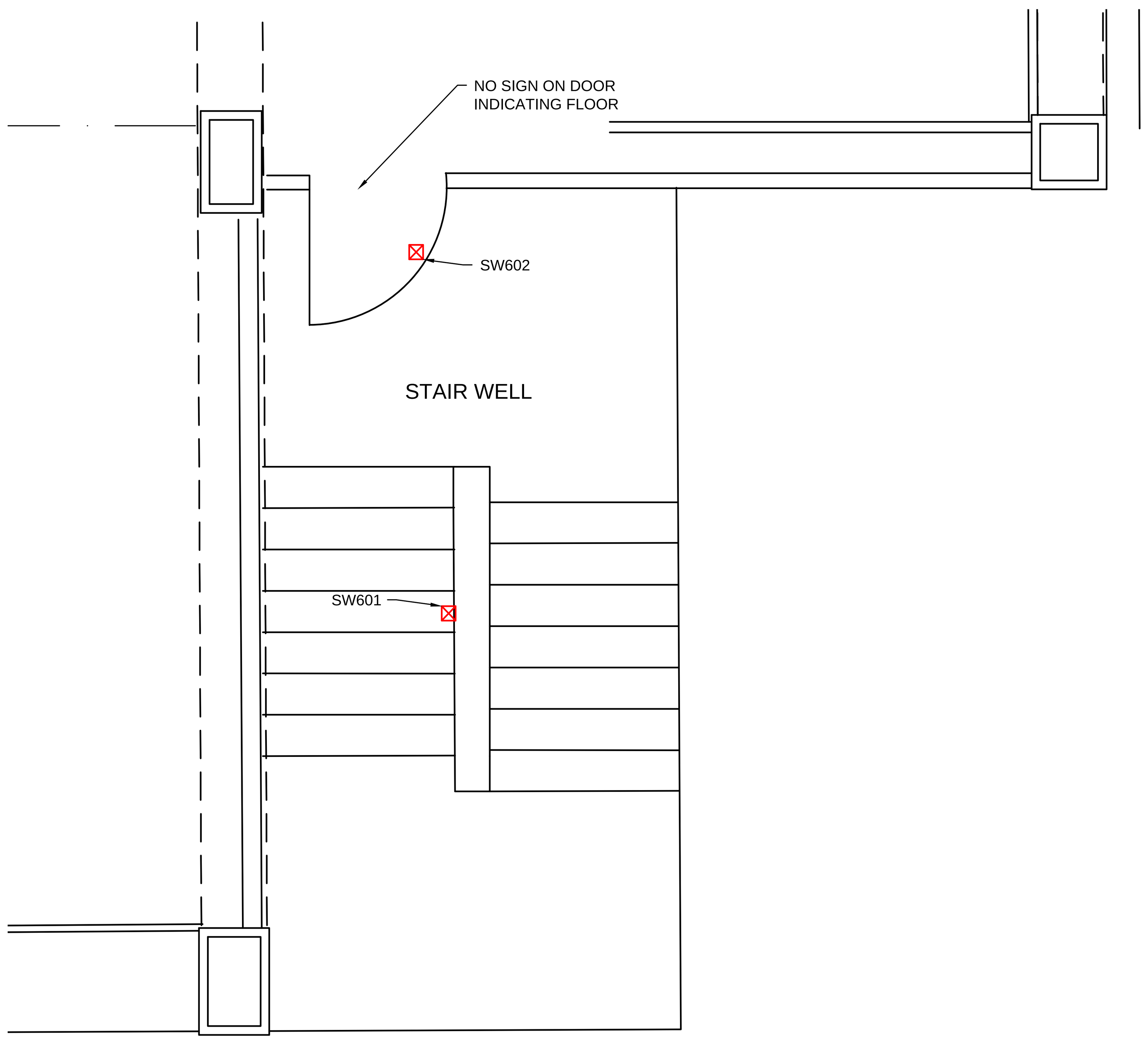
Drawing No. 673846-TG-112

Revision A

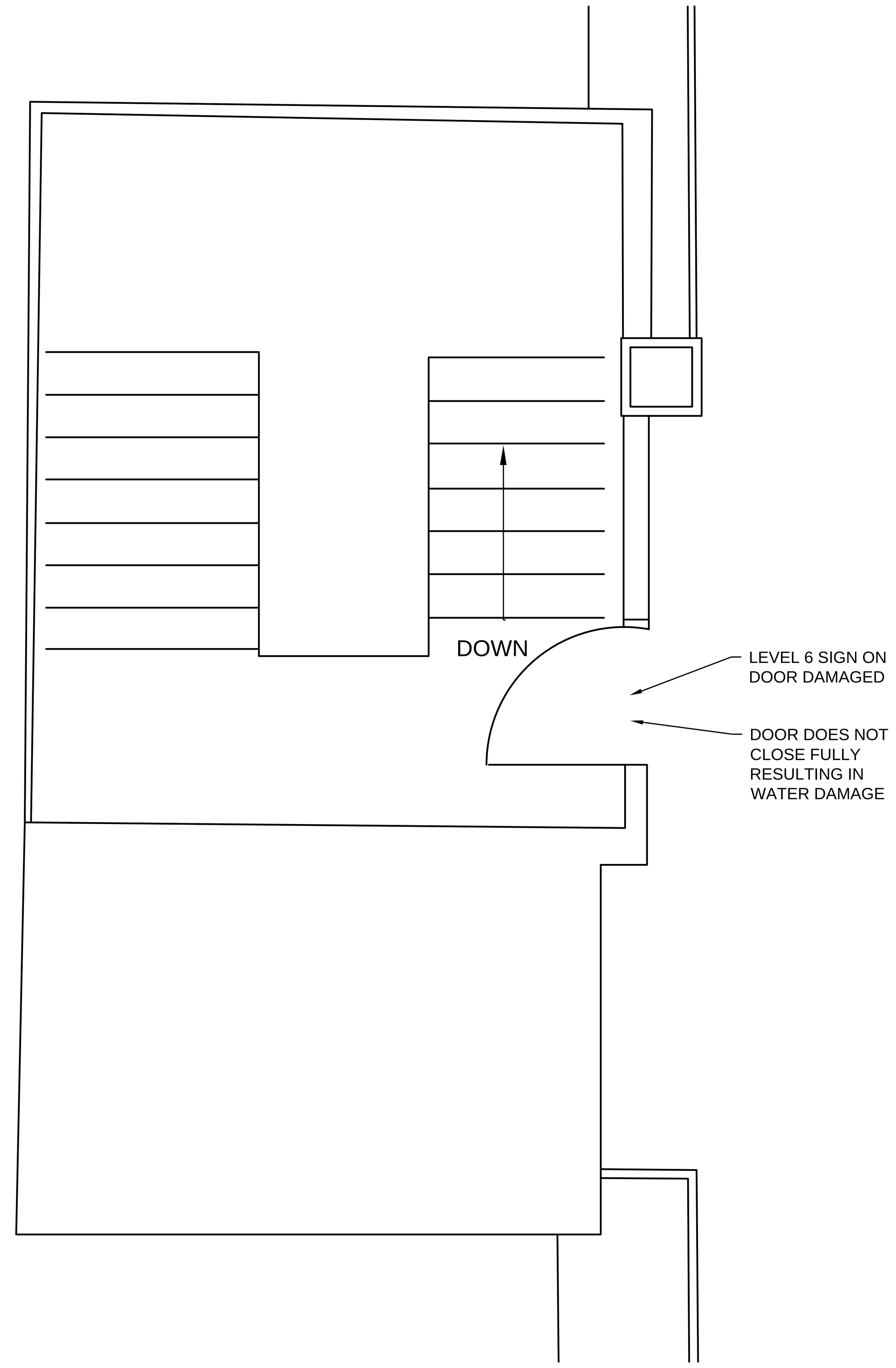
Drawing Scale: NTS




## LEVEL 6 FLOOR PLAN
NOT TO SCALE




## DETAIL 2
NOT TO SCALE




## DETAIL 1
NOT TO SCALE

| CONCRETE REPAIR SCHEDULE - STAIR WELLS | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| SW601 | 100 | 250 |
| SW602 | 100 | 250 |



KEY

☒ STAIR WELL DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client

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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE
LEVEL 6
STAIRCASE DEFECTS

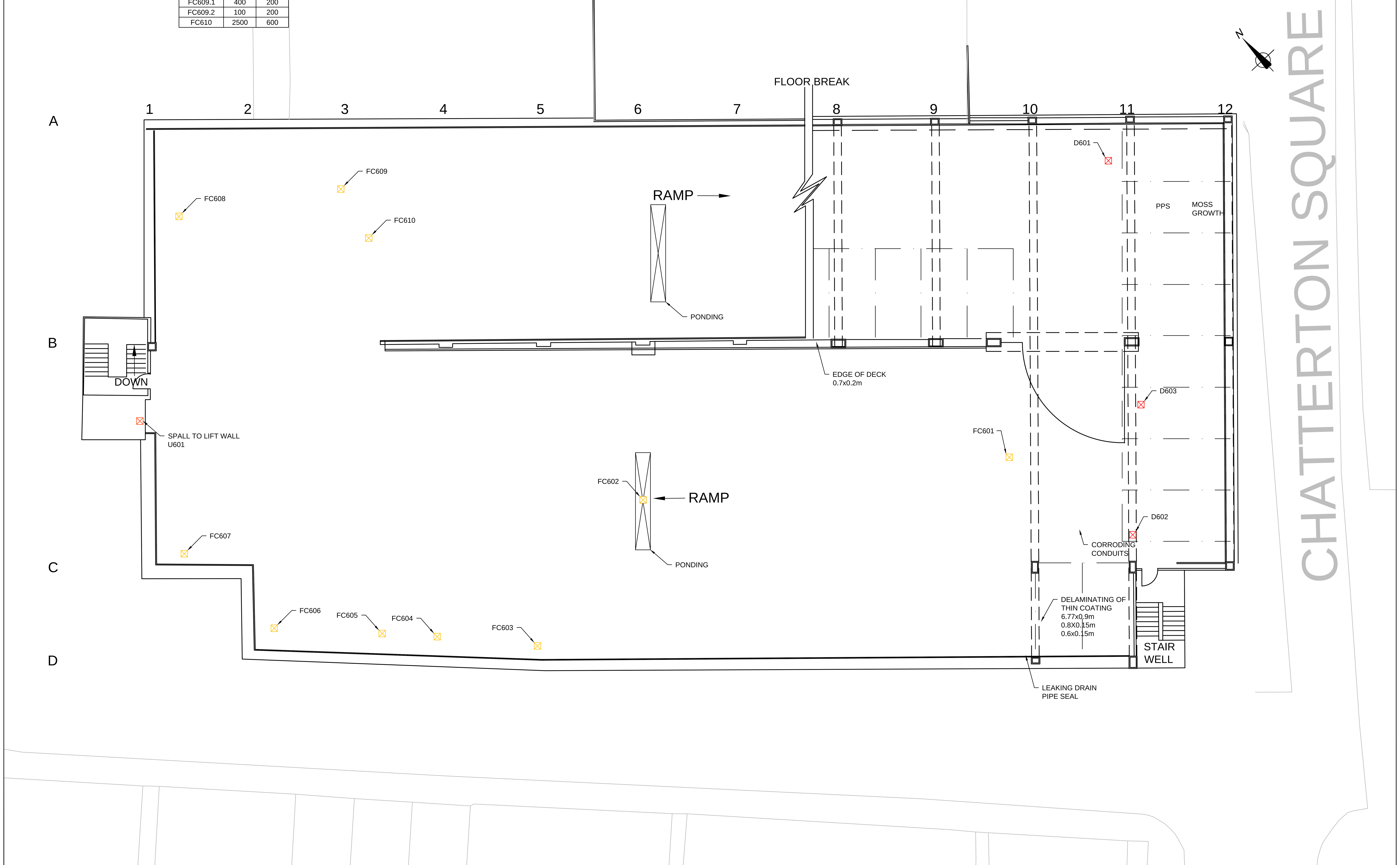
Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-113
Revision A

Drawing Scale: NTS

| CONCRETE REPAIR SCHEDULE - DECK | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| D515 | 100 | 100 |
| D516 | 100 | 150 |
| D601 | 150 | 100 |
| D602 | 500 | 200 |
| D603 | 100 | 100 |

| FAILED SURFACING SCHEDULE | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| FC601.1 | 3400 | 400 |
| FC601.2 | 1000 | 350 |
| FC601.3 | 400 | 250 |
| FC601.4 | 600 | 650 |
| FC602 | 7250 | 1550 |
| FC603 | 2600 | 650 |
| FC604.1 | 350 | 100 |
| FC604.2 | 250 | 100 |
| FC605 | 100 | 100 |
| FC606 | 550 | 750 |
| FC607.1 | 400 | 250 |
| FC607.2 | 850 | 100 |
| FC607.3 | 100 | 100 |
| FC608 | 250 | 100 |
| FC609.1 | 400 | 200 |
| FC609.2 | 100 | 200 |
| FC610 | 2500 | 600 |




## LEVEL 6 FLOOR PLAN

NOT TO SCALE



## KEY

PPS: PEELING PAINT SOFFIT

DECK DEFECT

FAILED SURFACING

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

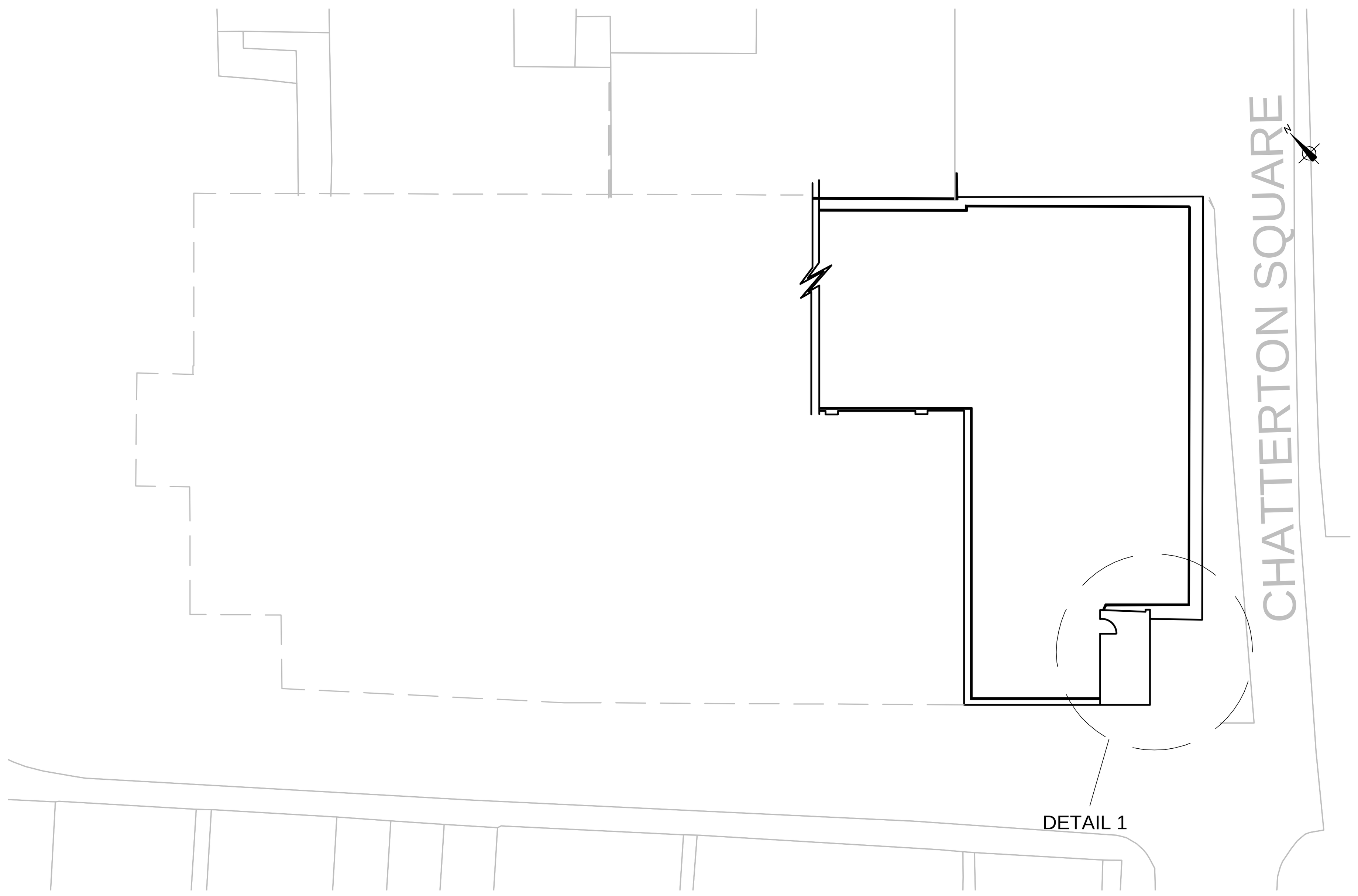
TEMPLE GATE LEVEL 6 DEFECTS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-114

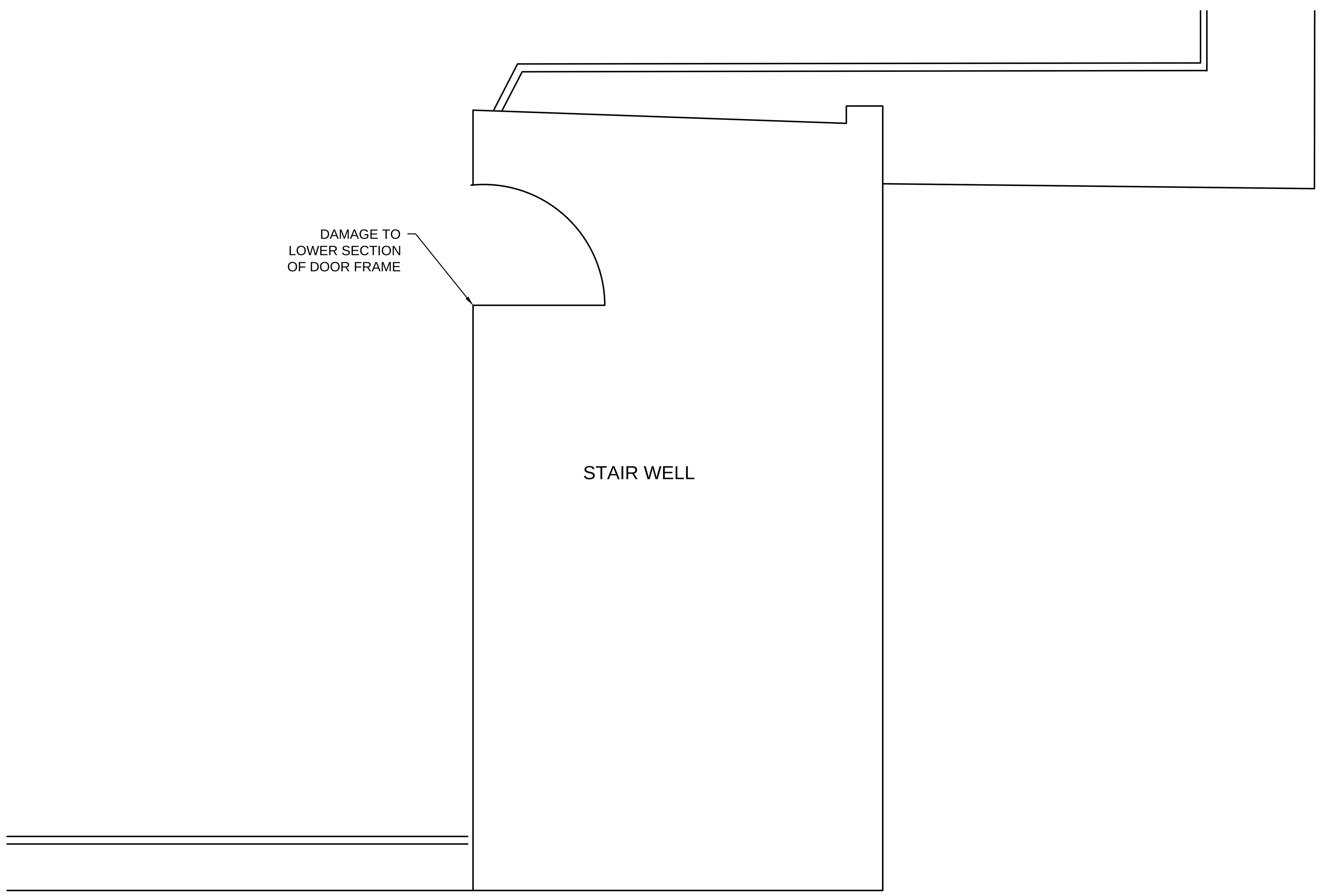
Revision A

Drawing Scale: NTS




LEVEL 7 FLOOR PLAN

NOT TO SCALE




DETAIL 1

NOT TO SCALE



| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client

CH2M HILL
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Project

TEMPLE GATE MULTI STOREY
CAR PARK STUDY

Drawing

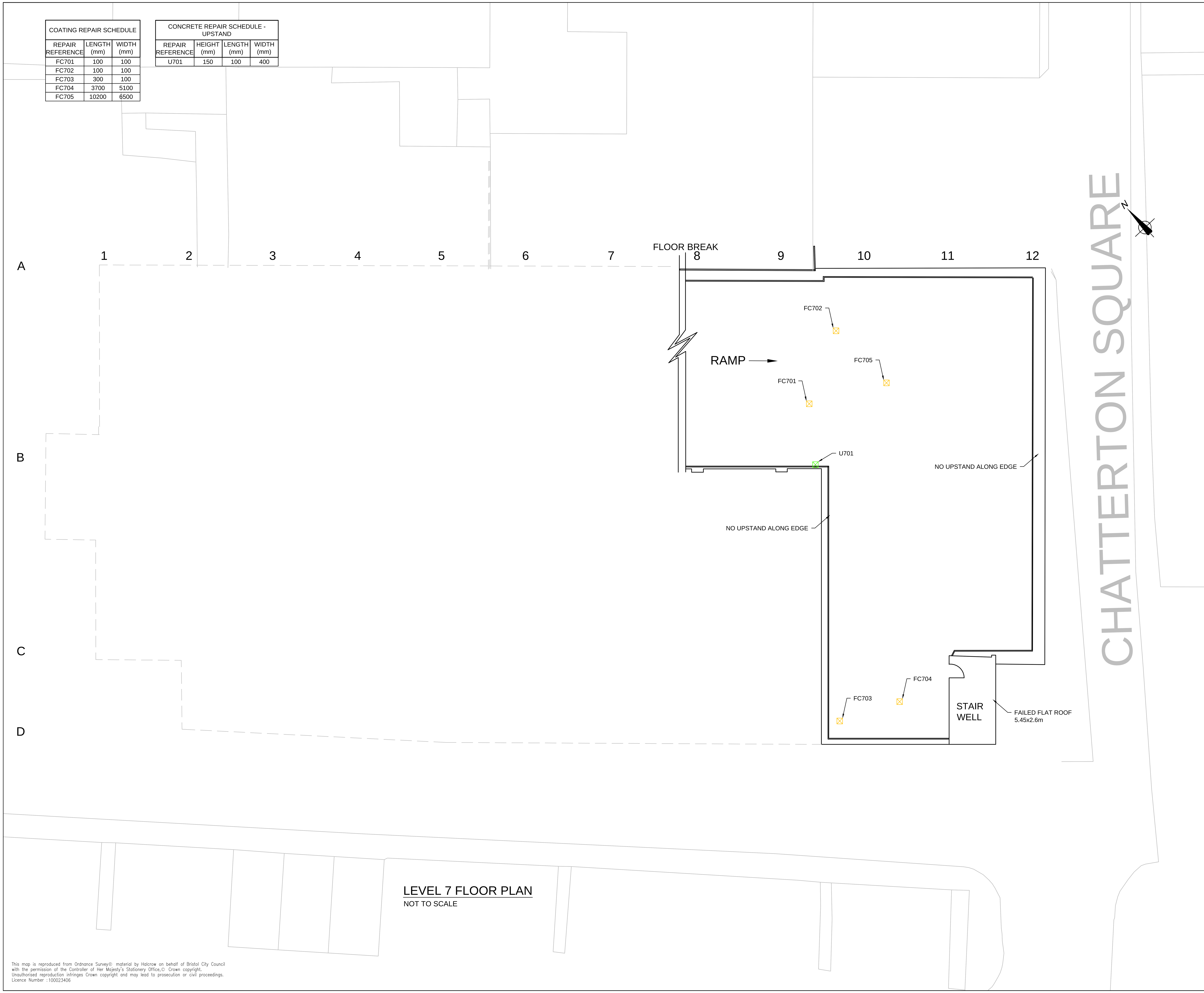
TEMPLE GATE
LEVEL 7
STAIRCASE DEFECTS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-115

Revision A

Drawing Scale: NTS




## LEVEL 7 FLOOR PLAN

NOT TO SCALE

| COATING REPAIR SCHEDULE | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| FC701 | 100 | 100 |
| FC702 | 100 | 100 |
| FC703 | 300 | 100 |
| FC704 | 3700 | 5100 |
| FC705 | 10200 | 6500 |

| CONCRETE REPAIR SCHEDULE - UPSTAND | | | |
|---|---|---|---|
| REPAIR REFERENCE | HEIGHT (mm) | LENGTH (mm) | WIDTH (mm) |
| U701 | 150 | 100 | 400 |

## KEY

PPS: PEELING PAINT SOFFIT

UPSTAND DEFECT

FAILED SURFACING

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE LEVEL 7 DEFECTS

Drawn by: FG Date: 13/02/2018

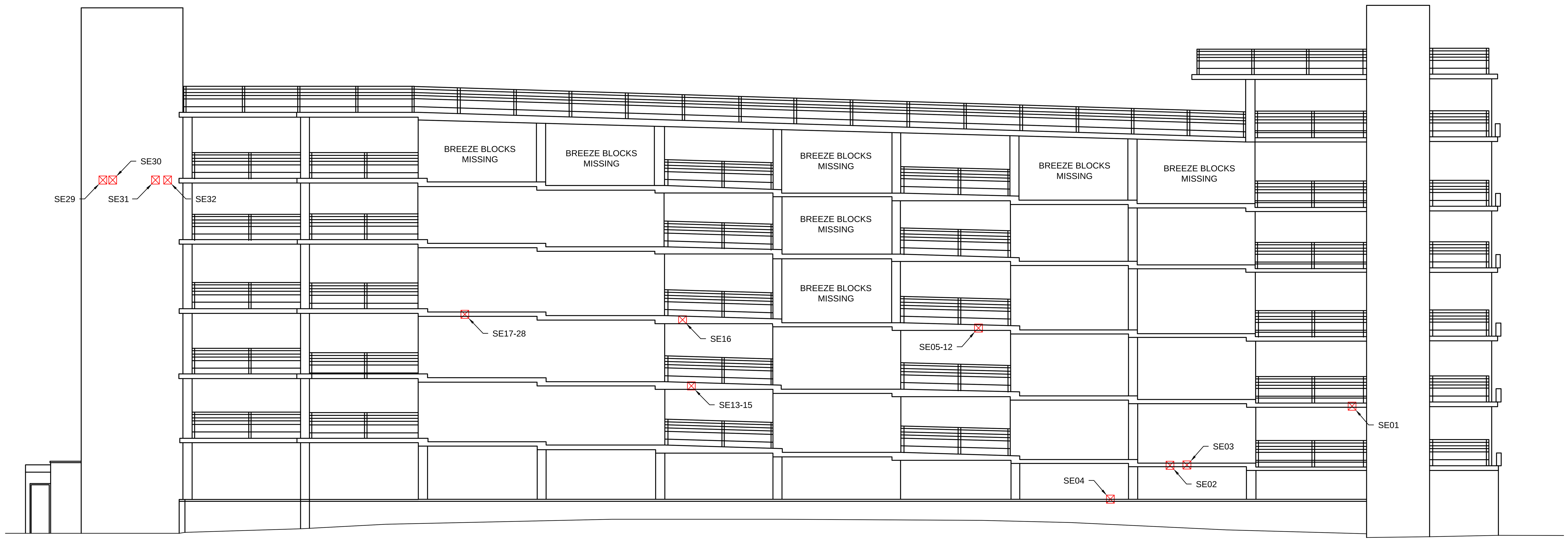
Checked by: AP Date: 13/02/2018

Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-116

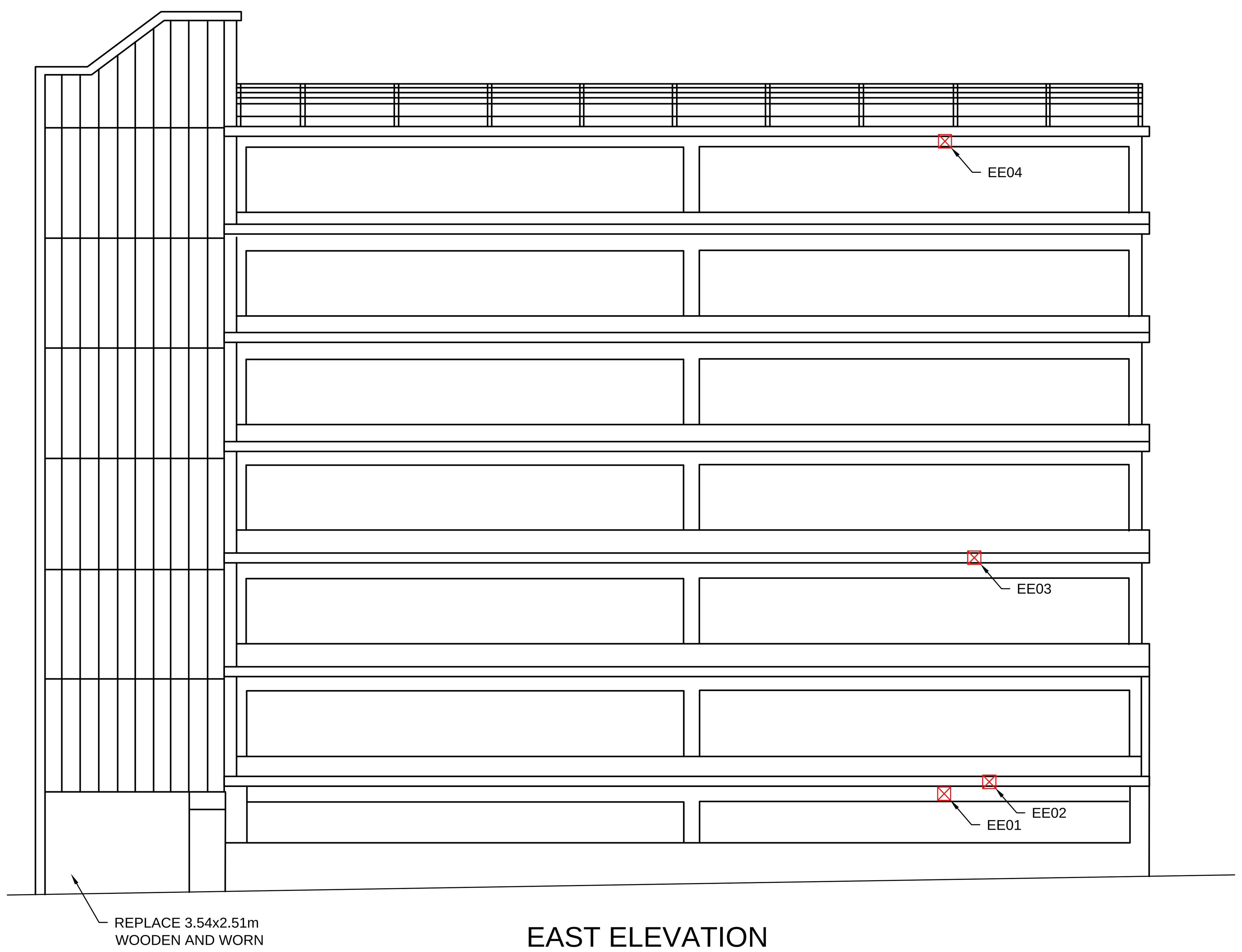
Revision A

Drawing Scale: NTS




SOUTH ELEVATION

NOT TO SCALE




EAST ELEVATION

NOT TO SCALE

| CONCRETE REPAIR SCHEDULE - SOUTH ELEVATION | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| SE01 | 100 | 100 |
| SE02 | 100 | 100 |
| SE03 | 100 | 100 |
| SE04 | 50 | 350 |
| SE05 | 100 | 100 |
| SE06 | 100 | 100 |
| SE07 | 100 | 100 |
| SE08 | 100 | 100 |
| SE09 | 100 | 100 |
| SE10 | 100 | 100 |
| SE11 | 100 | 100 |
| SE12 | 100 | 100 |
| SE13 | 100 | 100 |
| SE14 | 100 | 100 |
| SE15 | 100 | 100 |
| SE16 | 500 | 300 |
| SE17 | 100 | 100 |
| SE18 | 100 | 100 |
| SE19 | 100 | 100 |
| SE20 | 100 | 100 |
| SE21 | 100 | 100 |
| SE22 | 100 | 100 |
| SE23 | 100 | 100 |
| SE24 | 100 | 100 |
| SE25 | 100 | 100 |
| SE26 | 100 | 100 |
| SE27 | 100 | 100 |
| SE28 | 100 | 100 |
| SE29 | 100 | 100 |
| SE30 | 100 | 100 |
| SE31 | 100 | 100 |
| SE32 | 200 | 200 |

| CONCRETE REPAIR SCHEDULE - EAST ELEVATION | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| EE01 | 1200 | 400 |
| EE02 | ? | ? |
| EE03 | 200 | 200 |
| EE04 | 200 | 200 |



## KEY

☒ ELEVATION DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client


CH2M HILL
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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE SOUTH AND EAST ELEVATIONS

Drawn by: FG Date: 13/02/2018

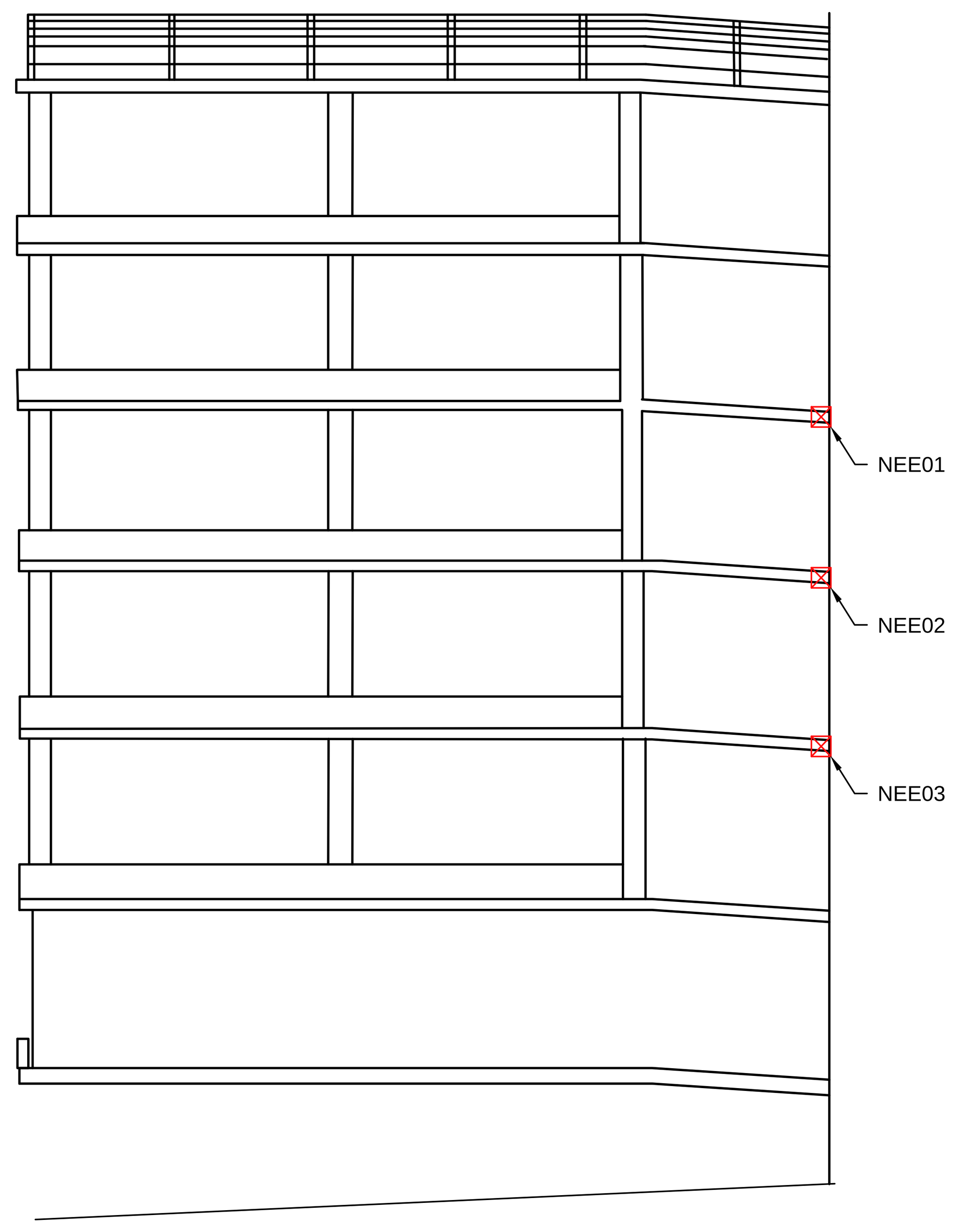
Checked by: AP Date: 13/02/2018

Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-117

Revision A

Drawing Scale: NTS




## NORTH EAST ELEVATION

NOT TO SCALE


## NORTH WEST ELEVATION

NOT TO SCALE


## WEST ELEVATION

NOT TO SCALE

| CONCRETE REPAIR SCHEDULE - WEST ELEVATION | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| WE01 | 100 | 100 |
| WE02 | 100 | 100 |
| WE03 | 100 | 100 |
| WE04 | 100 | 100 |
| WE05 | 100 | 100 |
| WE06 | 100 | 100 |
| WE07 | 100 | 100 |
| WE08 | 100 | 100 |
| WE09 | 100 | 100 |
| WE10 | 100 | 100 |
| WE11 | 100 | 100 |
| WE12 | 100 | 100 |
| WE13 | 100 | 100 |
| WE14 | 100 | 100 |
| WE15 | 200 | 100 |
| WE16 | 300 | 200 |
| WE17 | 200 | 200 |
| WE18 | 450 | 200 |

| CONCRETE REPAIR SCHEDULE - NORTH WEST ELEVATION | | |
|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) |
| NWE01 | 500 | 400 |
| NWE02 | 200 | 200 |
| NWE03 | 100 | 100 |
| NWE04 | 300 | 300 |

| CONCRETE REPAIR SCHEDULE - NORTH EAST ELEVATION | | | |
|---|---|---|---|
| REPAIR REFERENCE | LENGTH (mm) | WIDTH (mm) | DEPTH (mm) |
| NEE01 | 500 | 175 | 150 |
| NEE02 | 750 | 175 | 150 |
| NEE03 | 1000 | 175 | 150 |



KEY

☒ ELEVATION DEFECT

| Rev | By | Chkd | Apprvd | Date | Description |
|---|---|---|---|---|---|
| A | FG | AP | RB | 13/02/2018 | FIRST ISSUE |

Client

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Project

TEMPLE GATE MULTI STOREY CAR PARK STUDY

Drawing

TEMPLE GATE
NORTH (EAST & WEST) AND WEST ELEVATIONS

Drawn by: FG Date: 13/02/2018
Checked by: AP Date: 13/02/2018
Approved by: RB Date: 13/02/2018

Drawing No. 673846-TG-118

Revision A

Drawing Scale: NTS

# Appendix B – Test certificates

# Quartz Scientific

7G Dukes Yard, Shakespeare Industrial Estate, Watford WD24 5AL
Tel: 01923 213983 Fax: 01923 247732
e-mail: mail@quartz-scientific.co.uk www.quartz-scientific.co.uk

E.D.S
Marine & Civil Engineering Contractors
Dragon House, 17 Sir Alfred Owen Way
Pontygwindy Industrial Estate
Caerphilly CF83 3HU

27 November 2017
EDS/14314/isj


## CERTIFICATE of ANALYSIS

**A7125**

Chloride content of concrete samples

| | | |
|---|---|---|
| Date received | : | 22 November 2017 |
| Mass received | : | 3 to 12 g |
| Type of sample | : | concrete dust |
| Date of analysis | : | 24 and 27 November 2017 |
| Method of testing | : | B.S.1881:Part 124:2015. |

| Sample ref. | Client's ref. | | Chloride content | |
|---|---|---|---|---|
| | | *mm* | *% by mass of* | |
| | | | sample | cement |
| 16900 | TA1 | 5-20 | 0.10 | 0.68 |
| 16901 | | 20-35 | 0.11 | 0.78 |
| 16902 | | 35-50 | 0.05 | 0.33 |
| 16903 | TA2 | 5-20 | 0.08 | 0.56 |
| 16904 | | 20-35 | 0.10 | 0.75 |
| 16905 | | 35-50 | 0.08 | 0.55 |
| 16906 | TA3 | 5-20 | 0.06 | 0.42 |
| 16907 | | 20-35 | 0.08 | 0.56 |
| 16908 | | 35-50 | 0.05 | 0.35 |
| 16909 | TA4 | 5-20 | 0.08 | 0.59 |
| 16910 | | 20-35 | 0.16 | 1.14 |
| 16911 | | 35-50 | 0.13 | 0.89 |
| 16912 | TA5 | 5-20 | 0.06 | 0.45 |
| 16913 | | 20-35 | 0.17 | 1.24 |
| 16914 | | 35-50 | 0.11 | 0.78 |
| 16915 | TA6 | 5-20 | 0.08 | 0.60 |
| 16916 | | 20-35 | 0.13 | 0.92 |
| 16917 | | 35-50 | 0.08 | 0.54 |
| 16918 | TA7 | 5-20 | 0.05 | 0.39 |
| 16919 | | 20-35 | 0.06 | 0.42 |
| 16920 | | 35-50 | 0.04 | 0.30 |

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Company No. 2126524 VAT Reg. No. 460 8231 61

| Sample ref. | Client's ref. | | Chloride content | |
|---|---|---|---|---|
| | | *mm* | *% by mass of* | |
| | | | sample | cement |
| 16921 | TA8 | 5-20 | 0.11 | 0.76 |
| 16922 | | 20-35 | 0.11 | 0.76 |
| 16923 | | 35-50 | 0.30 | 2.15 |
| 16924 | TA9 | 5-20 | 0.09 | 0.62 |
| 16925 | | 20-35 | 0.16 | 1.13 |
| 16926 | | 35-50 | 0.08 | 0.55 |
| 16927 | TA10 | 5-20 | 0.30 | 2.13 |
| 16928 | | 20-35 | 0.43 | 3.06 |
| 16929 | | 35-50 | 0.30 | 2.16 |
| 16930 | TA11 | 5-20 | 0.18 | 1.29 |
| 16931 | | 20-35 | 0.16 | 1.13 |
| 16932 | | 35-50 | 0.11 | 0.76 |
| 16933 | TA12 | 5-20 | 0.08 | 0.58 |
| 16934 | | 20-35 | 0.14 | 0.96 |
| 16935 | | 35-50 | 0.14 | 1.02 |
| 16936 | WE1 | 5-20 | 0.02 | 0.15 |
| 16937 | | 20-35 | 0.01 | 0.11 |
| 16938 | | 35-50 | 0.13 | 0.94 |
| 16939 | WE2 | 5-20 | 0.10 | 0.68 |
| 16940 | | 20-35 | 0.22 | 1.57 |
| 16941 | | 35-50 | 0.18 | 1.29 |
| 16942 | WE3 | 5-20 | 0.03 | 0.20 |
| 16943 | | 20-35 | 0.06 | 0.43 |
| 16944 | | 35-50 | 0.07 | 0.50 |
| 16945 | WE4 | 5-20 | 0.04 | 0.31 |
| 16946 | | 20-35 | 0.16 | 1.17 |
| 16947 | | 35-50 | 0.16 | 1.15 |
| 16948 | WE5 | 5-20 | 0.15 | 1.09 |
| 16949 | | 20-35 | 0.10 | 0.68 |
| 16950 | | 35-50 | 0.23 | 1.64 |
| 16951 | WE6 | 5-20 | 0.03 | 0.19 |
| 16952 | | 20-35 | 0.13 | 0.91 |
| 16953 | | 35-50 | 0.11 | 0.78 |
| 16954 | WE7 | 5-20 | 0.15 | 1.07 |
| 16955 | | 20-35 | 0.19 | 1.38 |
| 16956 | | 35-50 | 0.37 | 2.63 |
| 16957 | WE8 | 5-20 | 0.17 | 1.22 |
| 16958 | | 20-35 | 0.14 | 1.03 |
| 16959 | | 35-50 | 0.34 | 2.42 |

| Sample ref. | Client's ref. | | Chloride content | |
|---|---|---|---|---|
| | | *mm* | *% by mass of* | |
| | | | sample | cement |
| 16960 | WE9 | 5-20 | 0.06 | 0.45 |
| 16961 | | 20-35 | 0.27 | 1.95 |
| 16962 | | 35-50 | 0.64 | 4.60 |
| 16963 | WE10 | 5-20 | 0.01 | 0.09 |
| 16964 | | 20-35 | 0.02 | 0.13 |
| 16965 | | 35-50 | 0.06 | 0.46 |

Note: 14 % cement content was assumed for the calculations.

End of results

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UKAS TESTING 0262

61209/F

**Certificate No**
1

**Date of Test**
14/11/2017

## CONCRETE TEST RESULTS
## COMPRESSIVE STRENGTH AND DENSITY OF CORES

**BS EN 12504-1:2009, BS EN 12390-3:2009 and BS EN 12390-7:2009**

| | | | | |
|---|---|---|---|---|
| Sandberg Reference | | F91942 | F91943 | F91944 |
| Site Mark/Client Reference | | Beam | Deck | Column |
| Details: - Location<br>- Date of coring | | Beam<br>NA | Deck<br>NA | Column<br>NA |
| Date Received | | 7/11/2017 | 7/11/2017 | 7/11/2017 |
| Presence of abnormalities | | None | None | None |
| Reinforcement, (diameter/distance)[1] | mm | None | None | None |
| Aggregate, maximum nominal size | mm | 16 | 12 | 14 |
| Age at Test | days | NA | NA | NA |
| Method of end preparation | | HAC | HAC | HAC |
| Surface Moisture Condition at test | | Damp | Damp | Damp |
| Actual Core Lengths<br>- Minimum length, as received<br>- Maximum length, as received<br>- Prepared length<br>- Relation to length, as-received | <br>mm<br>mm<br>mm<br>mm | <br>68<br>85<br>52<br>20-65 | <br>85<br>90<br>54<br>25-70 | <br>80<br>85<br>53<br>25-70 |
| Mean Core Diameter (d)[m] | mm | 44 | 44 | 44 |
| Length/Diameter Ratio, λ | | 1.18 | 1.23 | 1.20 |
| Density[2] - Saturated condition | kg/m³ | 2450 | 2430 | 2450 |
| Saturation before Test | days | 7 | 7 | 7 |
| Maximum Load at Failure | kN | 91.5 | 84.4 | 96.7 |
| Mode of Failure[4] | | Normal | Normal | Normal |
| Compressive Strength[3]<br>(Measured Core Strength) | MPa (N/mm²) | 60.2 | 55.5 | 63.6 |
| Reinforcement Correction[5] | | - | - | - |
| **Compressive Strength[3]<br>Corrected In-Situ Strength[5]** | MPa (N/mm²) | 64.0 | 60.1 | 68.2 |

1 Centre of bar to core end, before and after end preparation (e.g. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm from the end after preparation).
2 Volume by water displacement, densities given to nearest 10kg/m³.
3 Compressive strength values given to nearest 0.1MPa (N/mm²).
4 'Normal' (symmetrical failure) or otherwise as described.
5 BS EN 12504-1, National Annex NA - equivalent in-situ cube (no adjustment for direction of drilling)

ND = Not determined. NA = Not applicable.

| | | | |
|---|---|---|---|
| **Client** | Edwards Diving Services Ltd<br>Dragon House<br>Sir Alfred Owen Way<br>Pontygwindy Industrial Estate<br>Caerphilly<br>CF83 3HU<br><br>For the attention of Mr Steve Richings | **Signed** | For Sandberg LLP |
| | | **Name** | John Gallagher |
| | | **Position** | Deputy Quality Manager |
| **Reference** | Order No. P8092/SR dated 2/11/2017 | **Date** | 16 November 2017 |