Government of **Western Australia**
Department of **Commerce**

Building Commission

FINAL REPORT
Perth Children's Hospital audit

April 2017

BUILDING COMMISSION AUDIT REPORT

PERTH CHILDREN'S HOSPITAL

An audit of contractor and product performance in the construction of the new Perth Children's Hospital

April 2017

Government of **Western Australia**
Department of **Commerce**

Contents

Glossary of terms, acronyms and abbreviations

Acronym/Term	Full title
ABCB	Australian Building Codes Board
ABF	Australian Border Force – an agency of the Commonwealth Government Department of Immigration and Border Protection
ACM	Asbestos containing materials
ACP	Aluminium composite panels
ADWG	Australian Drinking Water Guidelines
BCA	Building Code of Australia as contained in the National Construction Code Volumes 1 and 2
CRA	*Building Services (Complaint Resolution and Administration) Act 2011*
Cwth	Commonwealth
Deemed-to-satisfy provisions	Deemed-to-satisfy is a compliance method within the NCC, whereby if you meet the relevant provisions set out, you are 'deemed-to-satisfy' the relevant performance requirements.
EPDM rubber	Ethylene propylene diene monomer (M-class) rubber, a type of synthetic rubber
FRL	Fire resistance level
mg/L	Milligrams per litre
NATA	National Association of Testing Authorities
NCC	National Construction Code, containing the Building Code of Australia (BCA) as Volumes 1 and 2 and Plumbing Code of Australia (PCA) as Volume 3
OSH Act	*Occupational Safety and Health Act 1984*
OSH regulations	Occupational Safety and Health Regulations 1996
PCA	Plumbing Code of Australia as contained in the National Construction Code Volume 3
PCH	Perth Children's Hospital
Shim	A thin and often tapered or wedged piece of material, used to fill small gaps or spaces between objects
sqm	Square metre
URP	Unitised roof panel – the building component that included asbestos containing fibre cement sheeting
VBA	Victorian Building Authority
WA	Western Australia

WHS	*Work Health and Safety Act 2011 (Cwth)*
WMCS	WaterMark Certification Scheme

Glossary of parties

Acronym/Name	Full title
ALS	ALS Environmental – an independent NATA accredited laboratory
ARL	Analytical Reference Laboratory
Arrow Fire Services	Arrow Fire Services – fire doorset supplier
ARUP	ARUP Group Ltd – engaged by Strategic Projects as a façade engineer advisor
ASEA	Asbestos Safety and Eradication Agency
Aurecon	Aurecon Australia Pty Ltd – engaged by John Holland as consulting engineers for many aspects of the PCH including the façade design
Australian Border Force	Australian Border Force – an agency of the Commonwealth Government Department of Immigration and Border Protection
Blucher	Blucher (Australia) Pty Ltd
CFMEU	Construction, Forestry, Mining and Energy Union
ChemCentre	ChemCentre – analytical chemistry facility engaged by Strategic Projects for water quality testing
Christopher Contracting	Christopher Contracting Pty Ltd – licenced plumbing contractor
Coffey	Coffey International – asbestos materials consultant
Comcare	Comcare – Commonwealth Government agency established under the *Safety Rehabilitation and Compensation Act 1988*
Commissioner	Building Commissioner
CCEIC	Curtin Corrosion Engineering Industry Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Curtin	Curtin University
DFES	Department of Fire and Emergency Services
Department of Health	Department of Health – the PCH asset owner

Ecosafe	Ecosafe International
Focus	Focus Demolition and Asbestos Removalists – unrestricted licensed asbestos removal contractor
GCS	Global Construction Services Limited
Headerboard	Zhejiang Headerboard Building Materials Co., Ltd
IAQS	Indoor Air Quality Solutions
Jacobs	Jacobs Australia Pty Ltd – consultants for Strategic Projects on the water quality at Perth Children's Hospital
JMG	John Massey Group Pty Ltd – private building surveyor to Strategic Projects
John Holland	John Holland Pty Ltd – main building contractor for the Perth Children's Hospital
L&M Painting	Traleen Enterprises Pty Ltd, trading as L & M Painting Service – restricted licensed asbestos removalist
Lancall	Lancall Nominees Pty Ltd – occupational hygiene consultants
LeaderFlush	Leaderflush-Shapland Ltd – UK-based supplier of fire doorsets that went into receivership
Metlabs	Metlabs Australia – commissioned to report on the stainless steel corrosion
Microanalysis	Microanalysis – a testing laboratory testing water for lead content
MPL Laboratories	MPL Laboratories – a testing laboratory testing water for lead content
NDY	Norman Disney and Young Management Pty Ltd
NMHS	North Metropolitan Health Service, Department of Health
Occsafe	Occsafe Australia – consultant engaged by Yuanda (Australia) to undertake independent testing of products supplied by Yuanda on Australian building projects
Philip Chun	Philip Chun & Associates Pty Ltd – private building surveyor to John Holland
PLB	Plumbers Licencing Board
QEII	Queen Elizabeth II Medical Centre
QED	QED Environmental Services Pty Ltd

RED Fire Engineers	RED Fire Engineers – consultants to determine the compliance of Haidabond panels
Skillier	Skillier Australia – water testing subcontractor regarding stainless steel corrosion
Strategic Projects	Strategic Projects and Asset Sales division of the Western Australian Department of Treasury
Water Corporation	Western Australian Water Corporation
WorkSafe	WorkSafe division of the WA Department of Commerce
Yuanda (Australia)	Yuanda Australia Pty Ltd – façade design and construct subcontractor to John Holland
Yuanda (China)	Parent company of Yuanda Australia Pty Ltd
Zedcon	Zedcon Scientific Services

Figures, photographs, tables and graphs

1. Executive summary

This is the final report on the Building Commission's audit of the Perth Children's Hospital (PCH). The audit examined specific compliance and conformance issues, including:

- Asbestos:
  - unitised roof panels;
  - partial collapse of atrium ceiling; and
  - curtain wall components.
- Plumbing:
  - lead contamination in water;
  - stainless steel pipe corrosion; and
  - burst rubber expansion joint.
- Fire safety:
  - aluminium composite panels; and
  - fire doorsets.
- Other issues:
  - vitreous enamel panels; and
  - curtain wall glazing.

This report examines the:

- compliance of building materials used;
- extent of any incidence of non-compliance and how it was rectified; and
- conduct of registered or licensed contractors:
  - John Holland, registered building contractor;
  - Philip Chun, registered building surveyor contractor; and
  - Christopher Contracting, licensed plumbing contractor.

This audit considers whether the items examined have been completed in accordance with the plans and specifications, whether the building and plumbing laws were complied with and how the building and plumbing standards have been applied.

PCH is a complex project subject to a number of contractual disputes and issues between the parties involved. This audit does not examine contractual or liability issues, except to the extent they directly impact on the specific compliance and conformance issues.

The audit was carried out under the Building Commission's independent statutory powers.

The Building Commission's conclusions are summarised below.

1.1. Asbestos

Unitised roof panels

The unitised roof panels (URPs) containing asbestos were successfully rectified and there is now no risk of asbestos contamination of the PCH from the URPs.

Partial collapse of atrium ceiling

John Holland and its subcontractors have repaired or replaced all damaged ceiling panels.

Plasterboard ceiling panels became waterlogged because John Holland did not ensure the temporary URP remediation works were sufficiently sealed.

Curtain wall system components

Occsafe assessed all other components that Yuanda (Australia) supplied for PCH. They found no further asbestos contamination.

1.2. Plumbing

Lead contamination in water

Water supplied from end use fittings has not been approved by the Chief Health Officer as meeting the Australian Drinking Water Guidelines for lead.

Water supplied to the QEII campus by the Water Corporation contains negligible lead and does not contribute to lead contamination.

There are four potential sources of lead contamination:

1. Lead leaching from fittings in the ring main (fire hydrants, etc.).
2. Lead contained in residues in the ring main (including the dead leg).
3. Lead leaching from fittings in PCH plumbing (brass fittings and taps, etc.).
4. Lead contained in residues in the PCH water supply network (residues containing lead from PCH brass fittings, residues drawn in from the QEII ring main).

Brass plumbing fixtures and fittings in the PCH meet the required standards for lead content.

Flushing and filtering of water within PCH has reduced but not eliminated lead contamination.

The water and metallurgical testing for lead undertaken by the various parties to date has allowed potential sources to be identified but not the contribution, if any, of each source to the lead detected in the tests.

Until the source or sources of excessive lead is determined it is premature to find whether a registered or licensed contractor has acted appropriately.

Options to manage lead contamination are discussed in section 6.4.3.

Stainless steel pipe corrosion

Manufacturing defects are primarily responsible for the corrosion in the stainless steel pipes. Water quality may have increased the rate of corrosion.

John Holland did not contribute to the manufacturing defects that contributed to the stainless steel pipe corrosion.

Christopher Contracting did not contribute to the manufacturing defects that contributed to the stainless steel pipe corrosion.

Christopher Contracting should have taken more care to reduce the burrs and the resulting swarf from pipe cutting that the CCTV inspection discovered inside the stainless steel pipework.

Burst rubber expansion joint

The rubber expansion joint burst due to a failure in the building management system that allowed the water temperature to rise above the manufacturers specifications. The building management system has now been rectified and the expansion joint replaced.

1.3. Fire safety

Aluminium composite panels

Aluminium composite panels (ACPs) were audited to ensure that the PCH façade complies with the National Construction Code (NCC) due to the potential risk of the spread of fire.

John Holland and Philip Chun advised that the ACPs met the deemed-to-satisfy provisions of the NCC. The Building Commission is not satisfied that there is sufficient evidence to demonstrate that the Haidabond panels met the deemed-to-satisfy provisions of the NCC.

The Building Commission examined whether it was possible to demonstrate that the Haidabond panels met the NCC performance standards. The Building Commission engaged independent fire expert, RED Fire Engineers, to provide expert technical advice.

Based on RED Fire Engineers' investigation, the Building Commission is satisfied that the Haidabond panels installed at PCH meet the NCC performance requirements to avoid the spread of fire for a sprinklered building. A management-in-use procedure is required for times when the sprinklers are isolated (for example during maintenance).

Philip Chun should have obtained appropriate evidence to demonstrate the Haidabond panels met the NCC deemed-to-satisfy provisions of the NCC.

John Holland should have obtained appropriate evidence to be satisfied that the Haidabond panels complied with the project specification.

Fire doorsets

The fire doorsets initially supplied by Leaderflush-Shapland Ltd. (Leaderflush) did not comply with the relevant Australian Standards to meet the deemed-to-satisfy provisions of the NCC. Philip Chun identified the non-compliance. John Holland engaged CSIRO to report on how to gain compliance.

John Holland took appropriate actions to rectify the doorsets to meet the relevant standards. The PCH fire doorsets now meet the performance requirements of the NCC.

1.4. Other issues

Vitreous enamel panels

A proportion of the vitreous enamel (VE) panels supplied to the PCH were damaged in transport from the factory in China.

John Holland took appropriate action to use experienced subcontractors to manufacture and transport the original and replacement panels.

Curtain wall glazing

No compliance issues were identified that required remediation.

1.5. Conduct of registered or licensed contractors

In examining the specific items in this audit, the Building Commission has not identified conduct by the registered building contractor John Holland, registered building surveyor contractor Philip Chun, or licenced plumbing contractor Christopher Contracting that requires immediate disciplinary action.

Delayed completion, complaints, material failures and contractual disputes suggest that the registered building contractor may have failed to properly manage and supervise the project. The Building Commission will continue to review evidence from this audit, other inquiries and the resolution of disputes to determine whether any disciplinary action is required.

1.6. Recommendations

Recommendation 1 – Non-conforming products and materials

- The Building Commission recommends that the Building Minister's Forum concludes its current work on the issue of non-compliant and non-conforming building materials and products and the establishment of a national regulators forum to coordinate education and compliance activities.
- The Building Commission recommends that building contractors implement more thorough quality assurance and quality checking procedures when sourcing materials and components.

Recommendation 2 – Lead in the PCH plumbing network

Perth Children's Hospital

- The Building Commission recommends that the State appoints an independent organisation to review the existing test results and carry out whatever additional tests are needed to determine the proportions of lead that came from the identified sources of lead at the PCH.

Other new buildings

- The Building Commission recommends that the Building Ministers Forum requests the Australian Building Codes Board (ABCB) to collate existing test results and commission whatever new testing is required to determine whether lead leaching from brass plumbing fittings is contributing to lead levels above the Australian Drinking Water Guidelines (ADWG) in Australian buildings.

2. Perth Children's Hospital audit

2.1. Final report

This is the final report of the Building Commission's audit into the compliance and remediation of publically reported, or closely associated, incidents that arose during the construction of the new Perth Children's Hospital (PCH) at the QEII Medical Centre site. The incidents are listed in section 2.2.

The Building Commission is an independent body and has relied upon information provided by stakeholders in producing this report.

This report examines the causes of the problems identified in the audit scope, how they were addressed, and whether there is any ongoing concern for the operation of the PCH or the safety of its staff, patients or visitors.

The Building Commission published an interim report on 13 September 2016 on the discovery of asbestos in unitised roof panels. The final report further examines the issue of asbestos in light of new information, as well as assessing the remedial work undertaken to ensure the roof panels are asbestos-free.

2.2. Scope

The Building Commission's independent audit followed publically reported incidents during the construction of the PCH. The purpose of the audit is to assess whether, in respect to these incidents, the building has been completed in accordance with the plans and specifications, whether the building and plumbing laws have been complied with and how the building standards have been applied.

To do this, the Building Commission focused on the roles of registered and licensed contractors: John Holland, Christopher Contracting and Philip Chun. This was achieved by auditing the following issues:

- Asbestos:
  - unitised roof panels;
  - partial collapse of atrium ceiling; and
  - curtain wall components.
- Plumbing:
  - lead contamination in water;
  - stainless steel pipe corrosion; and
  - burst rubber expansion joint.
- Fire safety:
  - aluminium composite panels; and
  - fire doorsets.
- Other issues:
  - vitreous enamel panels; and
  - curtain wall glazing.

The PCH is a complex project subject to a number of contractual disputes and issues between the parties involved. This audit does not examine contractual or liability issues, except to the extent they directly impact on the specific compliance and conformance issues.

2.3. Background

The PCH will be the sole dedicated children's hospital for the State. With a budget of $1.2 billion, it covers 125,000m^2 across six treatment floors, two research floors and two basement levels. A helipad on the roof will service the QEII campus. The PCH will have 298 beds and is designed to allow for future expansion.

The PCH is one of the largest and most complex construction projects of its type in Western Australia. As is common with recent building projects, some of the components and systems were sourced internationally, due to innovation, cost and time constraints, and international specialist expertise.

The project manager is the Strategic Projects and Asset Sales division of the Department of Treasury (Strategic Projects). In 2009 Strategic Projects appointed John Holland to design and construct the PCH. John Holland appointed a number of consultants to assist with the design elements of the construction including Aurecon, Philip Chun and Yuanda (Australia). In relation to the plumbing work John Holland engaged Norman Disney and Young (NDY) to complete the design and specification for the building's hydraulic system and Christopher Contracting to carry out the plumbing work.

Construction began in 2011 and when completed PCH will be handed over to the Department of Health.

2.4. Audit methodology

On 15 July 2016 the Building Commissioner announced that the Building Commission would carry out an audit[1] of the PCH.

An audit team was established and the audit was conducted from July 2016 to March 2017. The audit methodology involved reviewing and analysing documentation, conducting site inspections and interviewing all participants.

Each of the issues identified in the audit scope was examined and reported on in the following format:

- **Introduction** — How did the problem come to light?
- **Background** — What do we know about this problem?
- **Standards** — Applicable standards including legislative requirements, Australian Standards, codes and guides.
- **Findings** — A comprehensive summary of the audit findings.
- **Rectification** — How was the issue managed? Is the rectification work suitable?
- **Conclusion** — Did John Holland meet its obligations as a registered builder?

  Did Philip Chun meet its obligations as a registered building surveyor?

  Did Christopher Contracting meet its obligations as a licensed plumber?

  Did the audit suggest any ongoing concern for the operation of PCH, or the safety of staff, patients or visitors?

[1] Department of Commerce – Building Commission, Audit of Yuanda building products webpage www.commerce.wa.gov.au/building-commission/audit-yuanda-building-products

2.4.1. Consultation with stakeholders

Preliminary meetings were held with John Holland and Strategic Projects to advise that an audit would be undertaken. There was ongoing communication with both parties throughout the audit.

Other participants consulted include:

- Yuanda (Australia);
- Construction, Forestry, Mining and Energy Union (CFMEU);
- Philip Chun (consulting private building surveyor to John Holland);
- JMG (consulting private building surveyor to Strategic Projects);
- Christopher Contracting; and
- Blucher (Australia).

2.4.2. Liaison with government agencies

The audit team met with other government jurisdictions and agencies. The following agencies were consulted during the audit:

- Heads of Workplace Safety Authorities Imported Materials with Asbestos Working Group, via the Rapid Response Protocol;
- WorkSafe;
- Comcare;
- Department of Health;
- North Metropolitan Health Service,
- Child and Adolescent Health Service,
- Chief Health Officer,
- Australian Border Force;
- Water Corporation;
- Strategic Projects; and
- Department of Fire and Emergency Services (DFES).

Note: WorkSafe advised that health and safety regulators in New South Wales, Queensland, South Australia and Victoria were liaising with building owners and managers, as well as Yuanda (Australia), to test Yuanda (Australia) products in those states.

2.4.3. Review of documentation

Building Commission officers were provided with access to relevant documents, including information from Strategic Projects, John Holland, Yuanda (Australia), Philip Chun and Christopher Contracting. The Building Commission analysed this documentation to determine whether John Holland, Christopher Contracting and Philip Chun had taken proper care to ensure the PCH complied with applicable building and plumbing standards.

Documentation was reviewed for each issue audited, including:

- contract documents;
- emails and correspondence;
- plans;
- specifications;
- engineering details;
- certificates:
    - test certificates; and
    - compliance certificates, including CodeMark and WaterMark certificates.

- reports:
  - compliance reports;
  - inspection reports; and
  - internal reports.
- inspection camera footage;
- product test results;
- laboratory test results;
- technical building code reports;
- performance building code reports;
- technical building code reports from Philip Chun & Associates (consulting building surveyor to John Holland);
- performance building code reports from NDY (consulting fire engineer to John Holland);
- proposed remediation plans;
- DFES referral agency documents;
- manufacturers' product information and recommendations; and
- Bureau of Meteorology weather data.

2.4.4. Site visits

The audit team conducted a series of site visits to the PCH to examine the issues that were to be audited and to discuss the construction processes with participants.

2.4.5. Commissioning expert opinion

The Building Commission engaged an independent fire engineer, RED Fire Engineers to test and report on the performance of aluminium composite panels.

2.4.6. Plumbing inspections

Building Commission plumbing inspectors conducted site inspections with Christopher Contracting to identify possible causes of corrosion and to check the PCH plumbing installation for compliance with the plumbing standards. The plumbing audit included a review of product certification against the WaterMark Certification Scheme (WMCS).

The Building Commission consulted the stainless steel product suppliers and liaised with the administrator of the WMCS in relation to the 168.3mm diameter stainless steel piping installed in the PCH.

3. The Building Commissioner's auditing powers

3.1. The *Building Services (Complaint Resolution and Administration) Act 2011*

The *Building Services (Complaint Resolution and Administration) Act 2011* (CRA) enables the Building Commissioner to investigate the work and conduct of builders, building surveyors and plumbers (CRA s.86(i)).

A person authorised by the Commissioner may carry out an inspection of building compliance (CRA s.60). The Commissioner may authorise people to:

- monitor whether a builder or plumber is carrying out work with the required level of competency (CRA s.64); and
- inspect any building to ascertain:
  - how building services have been carried out; and
  - how building standards have been applied (CRA s.65).

The Commissioner may publish a statement identifying any building services carried out in an unsatisfactory or dangerous manner (CRA s.88).

3.2. Building Commission auditing team

To carry out the audit of the PCH the Building Commission established a team consisting of:

- three building surveyors;
- three plumbing inspectors;
- a senior investigator; and
- support staff.

The building surveyors are registered building surveyor practitioners and have relevant experience in the assessment and approval of commercial and industrial buildings.

The plumbing inspectors are licensed plumbers, hold Certificate IV in Government Investigations and have extensive experience in assessing plumbing compliance for private sector and government projects.

In addition, WorkSafe provided a scientific officer and an operational director to assist the audit team, and the auditing team contracted RED Fire Engineers, Microanalysis, MPL Laboratories and ChemCentre for their specialised expertise.

The audit was overseen by both the Audit Manager and Director of the Building Commission's compliance directorate.

4. Relevant laws

4.1. Building legislation and standards

4.1.1. The *Building Act 2011* (WA)

The *Building Act 2011* (Building Act) prescribes standards for the construction, demolition and occupancy of all buildings in Western Australia.

The Building Act came into effect on 2 April 2012. Construction of the PCH began in January 2012. As a state government building the PCH was not required to obtain a building permit, and is also exempted from getting an occupancy permit.

Notwithstanding these exemptions, the Building Commissioner's auditing powers under the CRA Act enable the Commissioner to provide advice on the PCH.

4.1.2. National Construction Code

The National Construction Code (NCC) consists of three volumes. Volumes one and two form the Building Code of Australia (BCA). Volume 3 is the Plumbing Code of Australia (PCA).

The 2011 edition of the NCC, and referenced Australian Standards, are the relevant measure for construction compliance for the PCH.

4.2. Plumbing legislation and standards

Plumbing in Western Australia is controlled through the following:

- *Plumbers Licensing Act 1995*.
- Plumbers Licensing and Plumbing Standards Regulations 2000.
- Plumbing Code of Australia.
- AS/NZS 3500 Parts 1, 2 and 4:
    - *AS/NZS 3500.1 Plumbing and drainage – water services;*
    - *AS/NZS 3500.2 Plumbing and drainage – sanitary plumbing and drainage;* and
    - *AS/NZS 3500.4 Plumbing and drainage – heated water services.*
- WaterMark Certification Scheme.
- *AS 3688-2005: Water supply – Metallic fittings and end connectors.*
- Australian Drinking Water Guidelines.

These requirements are discussed in more detail in section 6.3.

4.3. Asbestos legislation

4.3.1. The *Work Health and Safety Act 2011* (Cwth)

Under the *Work Health and Safety Act 2011* (WHS Act) licensed national employers must have workers' compensation insurance to cover their workplaces, systems and workers. Comcare is the agency responsible for ensuring compliance with the WHS Act.

As a self-insured licensee, John Holland's workplace health and safety practices must comply with the WHS Act. John Holland is responsible for ensuring, as far as is reasonably practical, that the PCH construction site does not present a risk to the health and safety of any person.

4.3.2. The *Occupational Safety and Health Act 1984* (WA)

On the PCH, the health and safety of employees and subcontractors who are not self-insured under the WHS Act are covered by the WA *Occupational Safety and Health Act 1984* (OSH Act). The OSH Act requires employers to provide and maintain a safe working environment for their employees, contractors and members of the public.

The Occupational Safety and Health Regulations 1996 require that articles containing asbestos not be used at workplaces. Any asbestos found at a workplace must be managed in accordance with the Code of Practice for the Management and Control of Asbestos in Workplaces (2005). In addition, the Worksafe Commissioner must be notified as soon as practicable where people at a workplace may have been exposed to asbestos.

4.3.3. Health (Asbestos) Regulations 1992 (WA)

The Health (Asbestos) Regulations 1992, made under the *Health Act 1911*, declare asbestos to be a hazardous substance. A person who uses, stores, cuts, repairs, removes, or disposes of any material containing asbestos without taking reasonable measures to prevent asbestos fibres entering the atmosphere commits an offence.

'Reasonable measures' include:

- using water to minimise airborne asbestos;
- using only non-powered hand tools or power tools that incorporate attachments designed to collect asbestos fibres;
- using only vacuum cleaning equipment designed to collect asbestos fibres;
- not using a high pressure water jet, or compressed air;
- ensuring that material containing asbestos is not broken or abraded; and
- ensuring that waste containing asbestos is disposed of in accordance with the Environmental Protection (Controlled Waste) Regulations 2000.

4.3.4. The *Customs Act 1901* (Cwth)

The *Customs Act 1991* prohibits the importation of all forms of asbestos and goods containing asbestos into Australia.

5. Asbestos

5.1. Introduction

On Monday 11 July 2016, workers on the PCH cut into unitised roof panels (URPs) to fit an additional mechanical smoke exhaust fan system through the atrium roof. On Tuesday 12 July 2016, in light of reports of asbestos being found in a building site in Brisbane the previous day, the workers examined fragments from the URPs and alerted John Holland when they became concerned about potential asbestos contamination. John Holland arranged laboratory testing and the fragments were found to contain white asbestos, or chrysotile – a banned substance in Australia.

5.2. Background

5.2.1. Asbestos in unitised roof panels

The Building Commission audit team, with significant contribution from WorkSafe, examined the issue of asbestos in the URPs, focusing on:

- how the initial incident was managed;
- procurement processes, to discover how contaminated URPs entered the supply chain; and
- asbestos removal and remediation process.

The first two of these points were reported on fully in the PCH interim report[2], released on 13 September 2016. These details have not changed since the interim report's publication.

The remediation works had not been completed when the interim report was published. It has since been completed satisfactorily.

5.2.2. Partial collapse of atrium ceiling

While the URP remediation works were being undertaken, rain leaked through the roof in to the ceiling space. When a roof fails to keep moisture out, ceiling systems are typically the first affected. The water damaged a number of internal ceiling panels and on 20 September 2016 some of the panels collapsed into the atrium space.

A ceiling panel falling from the atrium ceiling is an obvious and serious safety hazard. As such the ceiling collapse was added to the scope of the audit. The audit assessed whether the ceiling collapse was a result of poor weatherproofing of the work being done to remove asbestos-contaminated fibre cement sheets.

The plasterboard that fell was part of the ceiling lining, which is a different building component to the URPs that contained asbestos. There was no risk of asbestos contamination from the ceiling failure.

5.2.3. Curtain wall system components

On Monday 11 July 2016 asbestos was found in packers/isolators (sometimes known as gaskets) to steel spigots at 1 William Street, Brisbane which was under construction at the time. The following day asbestos was discovered in the acoustic fibre-cement sheets of the URPs fitted to the roof of the PCH.

[2] Department of Commerce – Building Commission, Perth Children's Hospital interim report (2016), available at www.commerce.wa.gov.au/publications/perth-childrens-hospital-interim-report

A packer/isolator is a shaped sheet or ring sealing the junction between two surfaces. The packer/isolator containing asbestos in Brisbane was a non-rubber sheet packer/isolator wrapped around steel spigots to prevent noise and friction. The gaskets used in the PCH are rubber and are installed in the curtain wall façade.

After the discovery of asbestos in two products, Yuanda contracted independent expert Occsafe Australia (Occsafe) to test their other products. All at-risk components from the PCH façade were tested.

Occsafe oversaw and appointed its own expert consultants to manage the tests. This involved identifying the correct materials for testing, taking samples and organising laboratory testing of each sample. The sampling procedures were carried out by appropriately qualified individuals and all tests were done by laboratories accredited by the National Association of Testing Authorities (NATA).

The Building Commission's audit reviewed the results of testing that was done to determine whether there was any asbestos-containing material (ACM) used in the PCH.

5.3. Standards

5.3.1. Requirements for asbestos

The Façade Works Package 17 Subcontract between John Holland and Yuanda (Australia) states *'The Subcontractor's attention is specifically drawn to and the Subcontractor shall comply with the provisions of the* [Health] *Act which prohibit the manufacture, supply, storage, transport, sale, use, re-use, installation and replacement of all forms of asbestos and asbestos-containing material with some limited exceptions'.*

The *Customs Act 1901* and the Customs (Prohibited Imports) Regulations 1956 prohibit the importation of asbestos or goods containing asbestos into Australia. From 31 December 2003, it has been unlawful to import, store, supply, sell, install, use or re-use asbestos-containing material.

The NCC does not mention asbestos.

5.3.2. Requirements for roofs and ceilings

The relevant NCC performance requirement states that during construction and use a building or structure must:

- perform adequately under all reasonably expected design actions;
- withstand extreme or frequently repeated design actions;
- be designed to sustain local damage, with the structural system as a whole remaining stable and not being damaged to an extent disproportionate to the original local damage; and
- avoid causing damage to other properties by resisting the actions to which it may reasonably be expect to be subjected. (NCC Vol 1 BP1.1(a)).

The NCC further requires that a roof and external wall (including openings around windows and doors) must prevent the penetration of water that could cause:

- unhealthy or dangerous conditions, or loss of amenity for occupants; and
- undue dampness or deterioration of building elements. (NCC Vol 1 FP1.4).

The actions to be considered in designing a building include rain water action and ponding action. The Aurecon specification for PCH detailed that the roof was to be designed to withstand a rainfall intensity prescribed in AS/NZS 3500.3-2003 for a 1 in 500 year storm. This means the roof ought to have withstood 258mm per hour of rain.

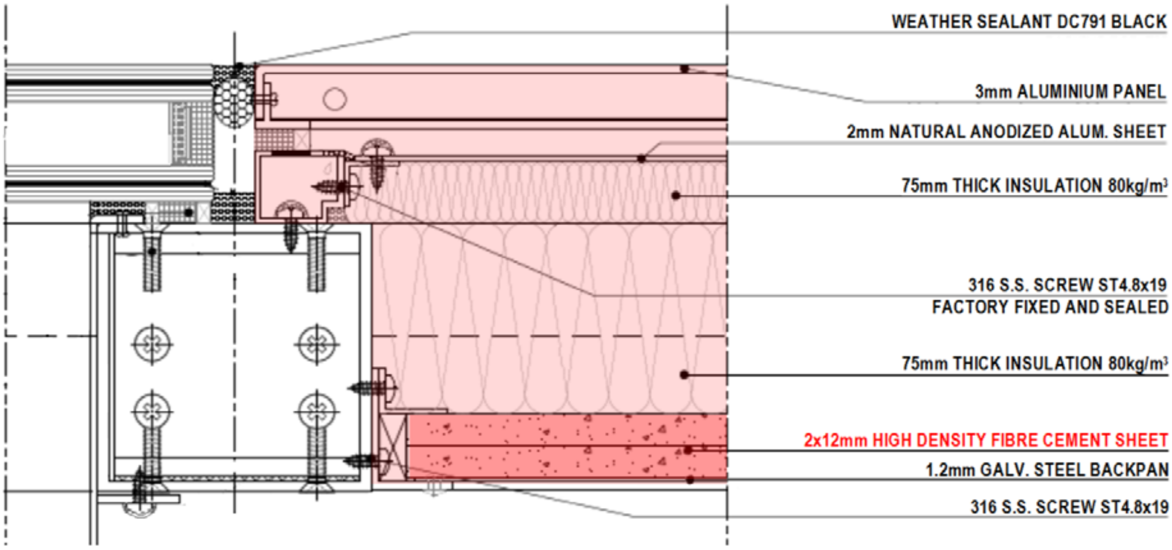
5.4. Unitised roof panels

5.4.1. Findings

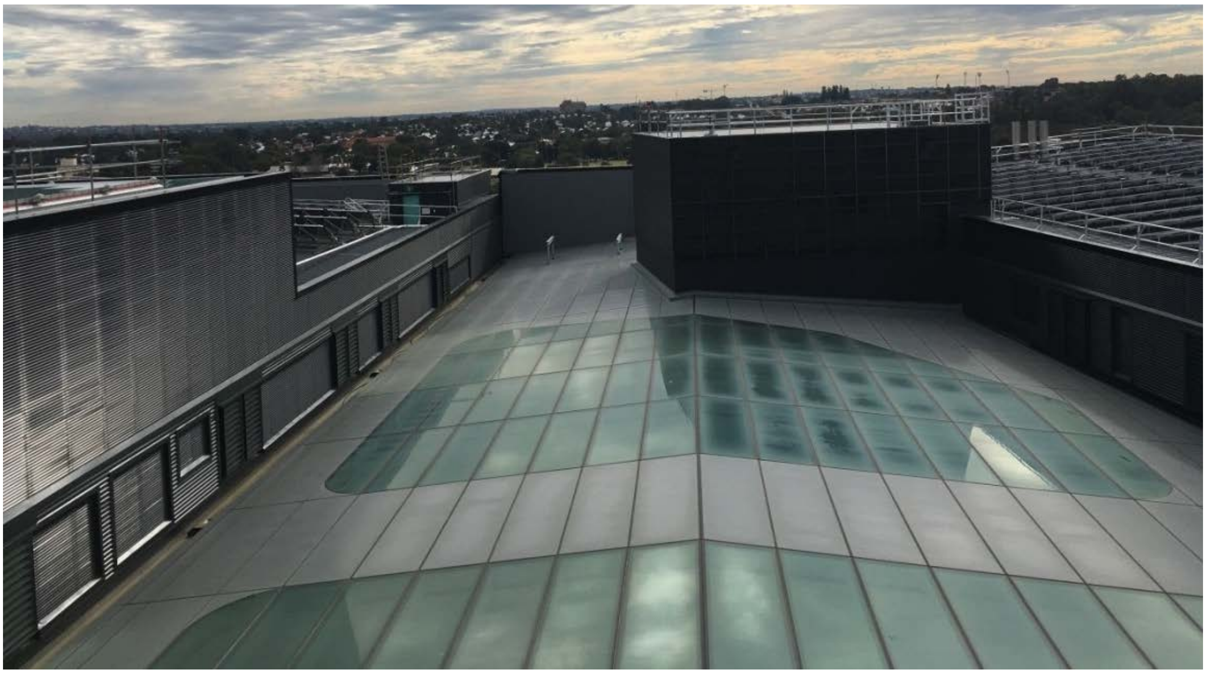
This section updates the findings published in the interim report on 13 September 2016. These findings have not changed since the release of the interim report. It should be read in association with the interim report.

The URPs are a type of sandwich panel. Two layers of fibre cement sheeting sit beneath a core of synthetic mineral fibre insulating batts (see Figure 1). This fibre cement sheeting was found to contain asbestos.

Figure 1: Sectional diagram of unitised roof panel, shaded in red, showing location of asbestos-containing fibre cement sheeting

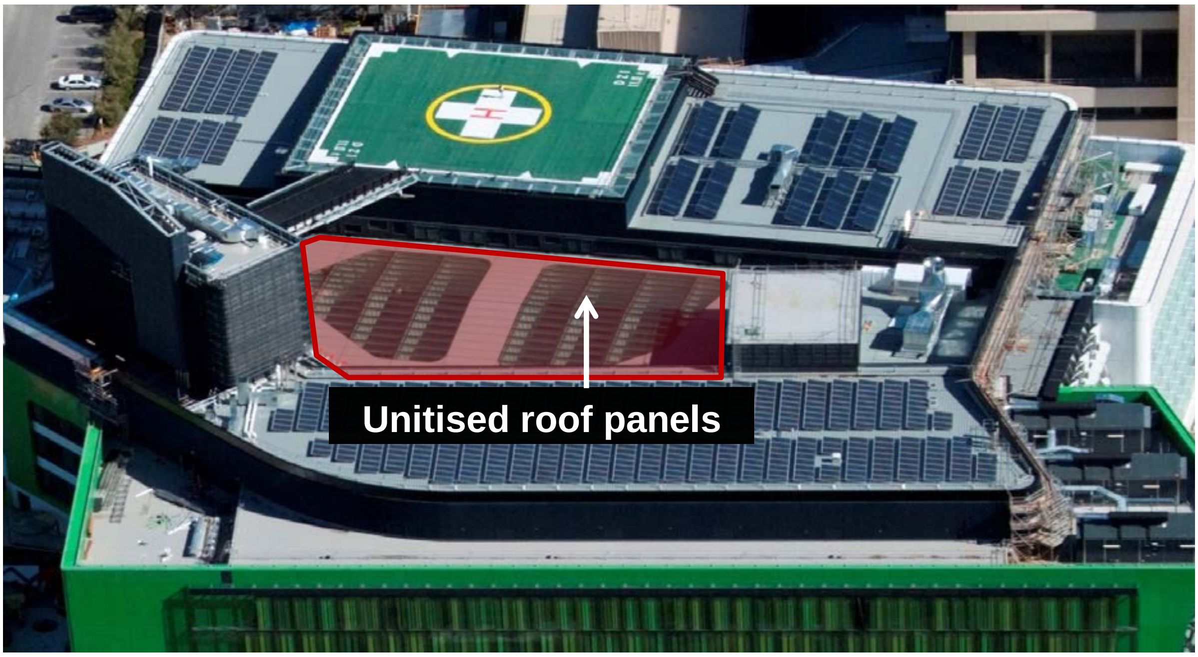


Photograph 1: Unitised roof panels installed at Perth Children's Hospital



The audit team was advised that the atrium roof included 174 URPs. They are restricted to a single area of the roof located above the level seven and level eight link bridges on the north balcony (see Photograph 1). The URPs were installed in mid-2014. They were custom-designed and made-to-measure, to provide an efficient and cost-effective installation. The URPs are situated over the atrium next to the roof-top helicopter landing pad, and were therefore required to meet stringent acoustic performance requirements (see Photograph 2).

Photograph 2: Helipad and unitised roof panels at Perth Children's Hospital



5.4.1.1. *Air, surface and bulk testing for asbestos*

The interim report (p. 16) noted that further testing was done in addition to the 280 tests covered by the interim report (see Table 1). These tests found no evidence of asbestos.

5.4.2. Rectification

The asbestos in the URPs at the PCH was rectified between August and November 2016.

John Holland's subcontractors removed and replaced the asbestos-containing, sound-proofing fibre cement sheets using the following process:

- Focus Demolition (Focus) (the licensed asbestos removal contractor) erected filtered, negative-pressure enclosures above individual URPs that were to be deconstructed. The enclosure controlled the asbestos hazard during the rectification work.
- GCS removed the top layer from the URP.
- Focus, in conjunction with Coffey (the ACM consultants) removed the ACM and provided clearance for the URP.
- GCS installed a temporary, weather-proof top layer in accordance with approved documentation.
- Once asbestos test results were clear, the enclosure was moved to the next panel to be deconstructed. There were four enclosures working at the same time.
- GCS replaced the fibre cement board and insulation and re-installed the top aluminium panel.

On 11 November 2016 John Holland wrote to the Building Commission advising that the rectification works were safely completed. John Holland advised that 189 URPs were rectified whereas Yuanda advised the number of URPs that required rectification was 132.

Fibre cement panels in 132 of the 189 atrium roof panels were found to contain asbestos. The remaining 57 panels contained a non-asbestos plasterboard material which was also changed to new cement sheeting. The original prototype design used plasterboard for sound dampening.

5.4.3. Conclusion

The URPs containing asbestos have been successfully rectified.

There is now no risk of asbestos contamination of the PCH from the URPs or other Yuanda-supplied materials examined by the Building Commission.

Table 1: Additional asbestos test reports

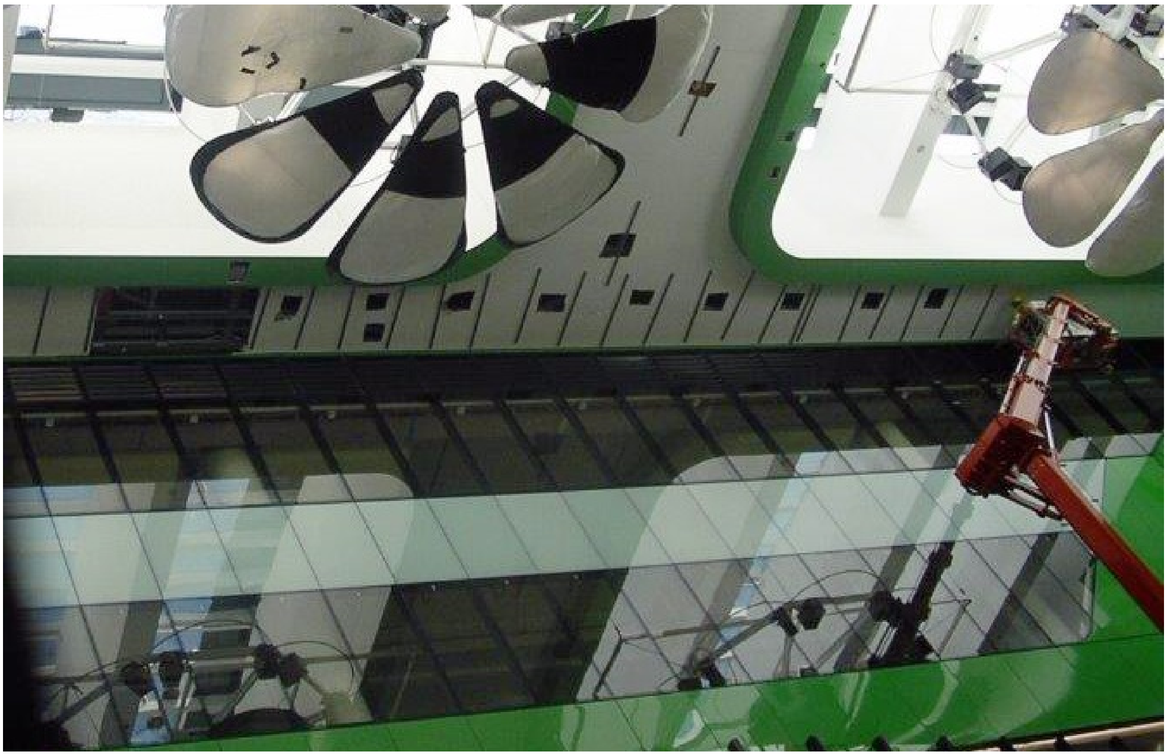
Bulk Sample Test Reports			
Date	**Laboratory**	**Report No**	**No of samples**
12 August 2016	Lifetree	BA1692	9
12 August 2016	Lifetree	BA1693	1
12 August 2016	Lifetree	BA1696	5
Air Sample Test Reports			
Date	**Laboratory**	**Report No**	**No of samples**
16 July 2016	Coffey	ENAUPERT05572AAL1A BW100680 - BW100685	5
18 July 2016	Coffey	ENAUPERT05572AAL4A BW100686 - BW100690	4
20 July 2016	Coffey	ENAUPERT05573AAL5A	6
21 July 2016	Coffey	ENAUPERT05573AAL8A	6
22 July 2016	Coffey	ENAUPERT05573AAL9A	12
23 July 2016	Coffey	ENAUPERT05572AAL5A	5
23 July 2016	Coffey	ENAUPERT05573AAL10A	12
24 July 2016	Coffey	ENAUPERT05572AAL6A	5
24 July 2016	Coffey	ENAUPERT05573AAL11A	10
25 July 2016	Coffey	ENAUPERT05572AAL7A	5
25 July 2016	Coffey	ENAUPERT05573AAL12A	7
26 July 2016	Coffey	ENAUPERT05572AAL8A	5
26 July 2016	Coffey	ENAUPERT05573AAL13A	7
27 July 2016	Coffey	ENAUPERT05572AAL9A	5
27 July 2016	Coffey	ENAUPERT05573AA_ACC2A BW100809 - BW100813	4
27 July 2016	Coffey	ENAUPERT05573AA_ACC3A BW100793 - BW100797	4
27 July 2016	Coffey	ENAUPERT05573AAL16B	4
28 July 2016	Coffey	ENAUPERT05573AAL23A	4
28 July 2016	Coffey	ENAUPERT05573AAL24A	4
13 August 2016	Coffey	ENAUPERT05572AA BW1001091 - BW1001099	8

Table 1: Additional asbestos test reports (cont)

Surface Samples Test Reports			
Date	**Laboratory**	**Report No**	**No of samples**
24 July 2016	Lifetree Environmental	BA1613	21
26 July 2016	Lifetree Environmental	BA1620	6
26 July 2016	Lifetree Environmental	BA1621	32
28 July 2016	Lifetree Environmental	BA1634	24

5.5. Atrium ceiling collapse

Photograph 3: Atrium ceiling collapse – initial works



5.5.1. Findings

Indoor Air Quality Solutions (IAQS), an industrial hygienist experienced in workplace damage, was engaged by John Holland to identify the extent of water damage not detectable by visual inspection. IAQS reported that '*following a period of heavy rain on 19 September 2016 areas of moisture ingress/damage were noted to be affecting isolated sections of the atrium ceiling. These moisture-affected areas were directly associated with roof panel remediation works being completed above*'.

Bureau of Meteorology rainfall records for Swanbourne, Fremantle, Subiaco, Perth Airport and Perth Metro show that there was negligible rainfall between 8 and 15 September 2016. Falls between 5.8–10.8mm were experienced on 16 September 2016. There was no further rainfall until 19 September 2016 when falls between 11–16.6mm were recorded. There was no further rainfall until 23 September 2016.

According to Strategic Projects, on 15 September 2016 just prior to the collapse, John Holland identified evidence of water leaking into the PCH atrium roof. This leak occurred because the weather proofing component was removed to rectify the URPs by John Holland.

This allowed water to seep into the void beneath the URPs and damage the insulation and ceiling panels below. John Holland subsequently added additional, temporary water-proofing to protect the area while subcontractors rectified the panels.

Despite the use of temporary lids and tarpaulins, John Holland advised that following heavy rain on 18 September 2016 water seeped into the ceiling space through the URP remediation works. Areas of the atrium's plasterboard ceiling became water damaged as a consequence.

John Holland advised that a visual inspection was undertaken on 19 September 2016 identifying areas of the ceiling on level 8 which appeared to be water damaged. After the inspection John Holland established a number of exclusion zones.

At 1:45pm on 20 September 2016, an approximately $1m^2$ section of waterlogged plasterboard and insulation fell from the level 8 atrium ceiling onto the level 5 balcony handrail, with smaller sections falling to the floor of the atrium. No one was injured.

Further exclusion zones were put in place and John Holland immediately notified the occupational safety and health regulators, Comcare and Worksafe. At 2:45pm another, similar-sized section of ceiling fell from level 8 onto the level 5 balcony and onto the atrium floor.

At approximately 3pm, East Block and West Block were evacuated.

5.5.2. Rectification

IAQS undertook a thermographic survey of all sections of the atrium ceiling on the morning of 20 September 2016. John Holland received the survey report at 10.30pm the same day.

On the evening of 20 September 2016, work began to rectify the ceiling damage including rapid drying to preserve the integrity of the ceiling. This work involved cutting holes in the ceiling where moisture had been detected by the IAQS thermographic images. Plasterboard and insulation were removed and affected areas reinforced with metal battens to prevent adjacent areas from pulling away from fixings during the drying process.

IAQS reinspected the affected area after 10 days of drying using fan-forced, ambient air through the open ceiling space. A small number of isolated areas were still affected by moisture.

On 30 September 2016 IAQS provided an interim report on the ceiling rectification, stating:

> *'Water ingress was affecting significant sections of the ceiling with moisture being held in ceiling insulation preventing effective drying by ambient air movement. A number of steps were taken to promote rapid drying to preserve the integrity of the ceiling material and minimise the likelihood of associated mould growth. These steps included accessing the water-affected areas via 'Big Red' (a large crane), cutting holes in the ceiling to remove wet insulation then securing the affected section with metal batons (*sic*) to prevent the sections pulling away from fixings during the drying process.'*

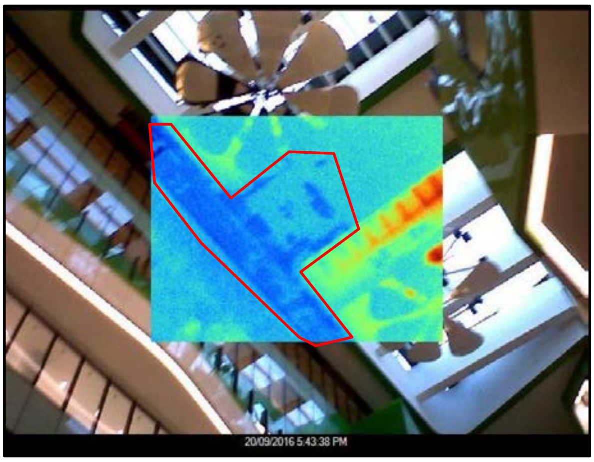
The report stated that there was no evidence of mould growth on the dried sections after 10 days. It also provided advice regarding mould growth, highlighting the conditions where mould growth may occur and what should be done if mould was found.

When thermographic and visual inspections confirmed that the ceiling had dried, new insulation was installed, and the plasterboard was replaced and painted.

Photograph 5 shows a thermographic image of the ceiling. The areas affected by moisture appear as dark blue. They are cooler due to evaporation of moisture from the ceiling surface. The area of glass appears as orange/red due to the higher outdoor temperatures.

Photographs 4 (left) and 5 (right): Photographic and thermographic images of water damage

Courtesy of Indoor Air Quality Solutions



After each subsequent period of heavy rain the thermographic survey was repeated, to confirm there were no further water leaks.

On 14 November 2016, the last of the rectification work to repair the water damage to the atrium ceiling was completed.

John Holland has installed five access panels above the ceiling and beneath the roof to provide access for future monitoring and inspection of the ceiling space.

In mid-November 2016 ARUP attended the PCH to review John Holland's proposal for additional sealing to the atrium roof panels to stop water ingress. John Holland advised that they were concerned with water leaking into the internal gutter system, which is not accessible. Whilst undertaking the onsite review ARUP observed that there seemed to be signs of corrosion on the galvanised backpan sheet within the URP. John Holland reviewed this corrosion and took action to deal with it. The Building Commission does not consider this corrosion as a significant matter now that the URPs are remediated.

5.5.3. Conclusion

The PCH roofing system was to be designed to withstand a rainfall intensity of 258mm per hour for a fully sealed, completed roof.

The Building Commission considers that plasterboard ceiling panels became waterlogged because John Holland and its subcontractors did not seal the temporary URP remediation works sufficiently to deal with the rain that occurred on 19 September 2016.

5.6. Curtain wall system components

5.6.1. Findings

Occsafe assessed all products Yuanda (Australia) supplied to PCH, and categorised the risk of each one potentially containing asbestos. Forty-five different products were identified and risks were categorised as high, medium, low and no risk. Products with no risk were not tested.

Occsafe was not able to take samples from the PCH site as John Holland did not permit it onsite due to a contractual dispute with Yuanda (Australia). Instead a damaged curtain wall panel from the PCH was transferred from site to Yuanda's Rockingham holding yard.

All materials identified as being at low, medium or high risk of containing asbestos were tested, including:

- thermal insulation;
- gaskets (EPDM rubber);
- plastic spacer/lining;
- single/double sided polyethylene tape;
- Sika membrane;
- polyamide thermal break;
- aluminium foil tape;
- door hardware; and
- stainless steel products.

All samples returned a negative result for asbestos.

WorkSafe confirmed that the risk assessment of products to be tested was appropriate and the final report and test results were satisfactory.

5.6.2. Rectification

No compliance issues were identified that required rectification.

5.6.3. Conclusion

The test results supplied by Occsafe and reviewed by WorkSafe show that the testing regime implemented by Yuanda (Australia) was satisfactory and that there were no positive test results for asbestos contamination in the curtain wall systems that Yuanda supplied to PCH.

6. Plumbing

6.1. Introduction

Throughout the construction of the PCH, Building Commission plumbing inspectors conducted regular inspections of plumbing work as part of their regulatory role under the Plumbers Licensing and Plumbing Standards Regulations 2000.

In early March 2016, Building Commission plumbing inspectors became aware that stainless steel pipes installed at PCH to supply drinking water were corroding and leaking.

In May 2016 lead levels above the Australian Drinking Water Guidelines (ADWG) were found in water samples from the PCH. Water was initially tested after Strategic Projects expressed concern that the flushing regime was insufficient and that microbial growth may be occurring.

On 15 June 2016 a rubber expansion joint (REJ) installed near a hot water pump in lower basement Plant Room 10 burst, pulling away from the flange on the discharge side of the pump.

6.2. Background

This part of the audit has examined the roles of John Holland, the registered building contractor and Christopher Contracting, the licensed plumbing contractor, in causing, identifying and rectifying the corrosion of stainless steel, the lead contamination and the REJ failure.

6.2.1. QEII Medical Centre water supply

The PCH forms part of the QEII Medical Centre.

The Water Corporation supplies water to QEII from the Mount Eliza reservoir. This scheme water is sourced from desalination plants (46%), catchment water (7%) and ground water (47%).

QEII is serviced by an internal ring main. The ring main is connected to the Water Corporation scheme water at two points, on Monash Avenue and Aberdare Road (see Photograph 6). The QEII ring main was originally part of the Water Corporation scheme water supply network and was subsequently handed over to the North Metropolitan Health Service (NMHS). The ring main is now controlled and maintained by the NMHS and supplies the majority of the QEII Medical Centre, including PCH.

The QEII ring main consists of a concrete-lined steel piping system, with a nominal diameter of 300mm. This system is approximately 50 years old and is a typical pipe construction for that time. A length of pipe, approximately 52m long and 300mm in diameter, has been part of the QEII ring main since 1969. This section of pipe has never been connected to a building. This means that no buildings have ever drawn water from the pipe and the pipe has remained charged with water from the ring main, creating a ‘dead leg’. The PCH was connected to the ring main at two points approximately 10m and 30m north of the dead leg (see Photograph 6). The water in the dead leg remained largely dormant or subject to very low flows for that period.

Before construction of PCH started, water samples from the ring main were tested by NDY. Tests showed the water quality was suitable for use at PCH.

The water and residues from the dead leg were tested by ALS Environmental (ALS) and were found to have accumulated heavy metals, sediment and biofilm. Additionally, ChemCentre tested for lead and also found raised lead levels.

Photograph 6: Indicative plan of QEII ring main water supply

6.2.2. PCH water supply

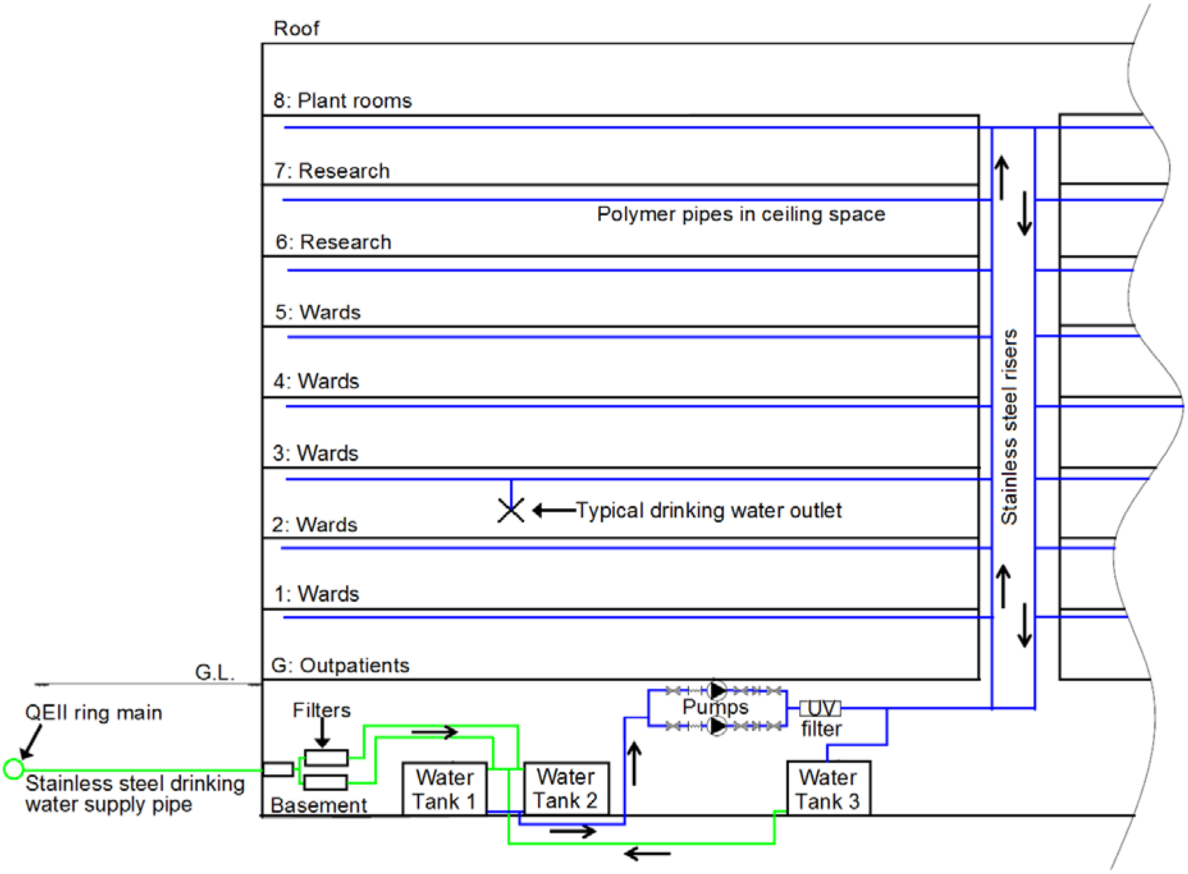
The QEII ring main supplies both drinking water and water for firefighting. The PCH has four separate feeds from the QEII ring main; two at the northern end and two at the southern end of the PCH. The north and south feeds each have separate pipes for firefighting and drinking water. These feeds were connected to the PCH in February 2015, bypassing the PCH water storage tanks in the first instance. Water was introduced to the PCH water storage tanks in January 2016.

The PCH has a complex plumbing network, with approximately 8km of pipework and more than 10,000 brass fittings and plumbing fixtures.

Drinking water enters PCH from the QEII ring main through polymer, cast iron and stainless steel pipes and fittings. Water passes through pre-filtration equipment and into storage tanks, before being pumped through ultra violet disinfection equipment and into a network of stainless steel horizontal pipes and risers serving a network of polymer pipes and brass fittings to outlets throughout the building (see Figure 2).

Heated water travels through solar panels and calorifiers via stainless steel pipes and risers, before entering the network of polymer pipes and brass fittings to the points of use (see Figure 3).

Figure 2: Indicative PCH cold water plumbing diagram



The drinking water supply system within the PCH is constructed of stainless steel pipes and brass fittings, with polymer pipes carrying water to outlets on each floor.

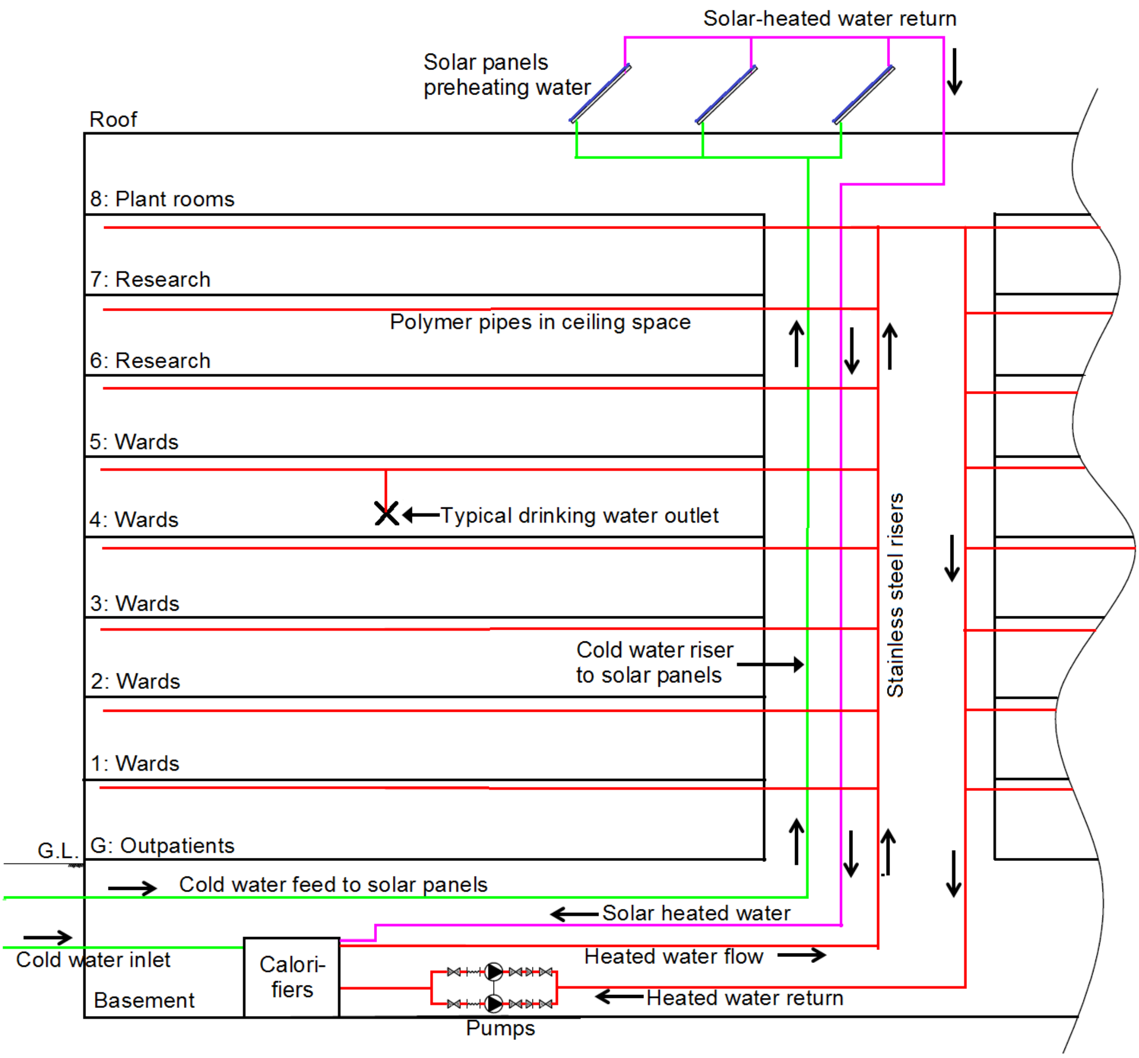
Up until the 1980s, copper pipe was mostly used for drinking water supply piping in Australia. Since then a range of innovative materials has been approved for use, including polymer (plastic) piping and fittings. In recent years stainless steel has been used more extensively in commercial installations due to its strength and durability.

There are only a few manufacturers of stainless steel drinking water supply pipe globally. The product used at the PCH was manufactured in Italy and Spain and sourced by an Australian-based supplier.

The stainless steel pipes and fittings that supply water in the PCH were installed using a performance solution under the NCC. The performance solution was necessary because jointing methods for stainless steel are not addressed in the deemed-to-satisfy standards (see section 6.3 Standards). The stainless steel jointing method used in the PCH is a 'press fit' system. An 'O' ring seals the joint and the pipe is then crimped to prevent longitudinal movement.

Corrosion has been detected in the stainless steel pipe network in the basement area and the supply pipes to the Central Sterile Supply Department (CSSD).

Figure 3: Indicative PCH heated water plumbing diagram



The PCH is served by a complex plumbing network and heating, ventilation and air conditioning (HVAC) system that includes significant plant, mostly located at basement levels. Plant Room 10, in the lower basement level, contains HVAC and hot water supply pumps and equipment. This network includes REJs supplied by Pacific Hoseflex Pty Ltd (Pacific Hoseflex), a company that originated in Australia with factories in Australia, China, Iran and Saudi Arabia. An REJ is commonly used to relieve piping stress and absorb pipe misalignment, compression, extension, noise and vibration.

6.3. Standards

6.3.1. The *Plumbers Licencing Act 1995*

Plumbing in Western Australia is regulated through the *Plumbers Licensing Act 1995* (the Act). The Act sets up the Plumber's Licensing Board (PLB) and the requirements for the licensing of plumbers.

The Act calls up the Plumbers Licensing and Plumbing Standards Regulations 2000 (Regulations). When construction began on the PCH, the Regulations referenced AS/NZS 3500 Parts 1, 2 and 4 as the plumbing standard required in WA.

The Regulations require the licenced plumbing contractor, in this case Christopher Contracting, to submit a notice of intention to the PLB 24 hours before commencing plumbing work. This notice was submitted on 7 October 2013.

6.3.2. Plumbing Code of Australia

The PCA and referenced standards set out:

- what materials may be used in plumbing installations; and
- what concentrations of hazardous metals such as lead are permitted.

The PCA references *AS/NZS 3500 Plumbing and drainage – Water services*; *Sanitary plumbing and drainage* and *heated water services* as deemed-to-satisfy solutions. AS/NZS 3500 requires that commissioning, including flushing, testing and disinfection, be carried out in plumbing installations that are fed from water storage tanks.

AS/NZS 3500 references *AS/NZS 4020 Testing of products for use in contact with drinking water*. AS/NZS 4020 includes tests for metals extracted from metal products that are in contact with drinking water.

The PCA allows for a performance solution to be used in place of a deemed-to-satisfy solution.

Note: The PCA requires that cold and heated water intended for human consumption, food preparation, food utensil washing or personal hygiene must be connected to a drinking water supply. A drinking water supply is defined in the PCA as water intended primarily for human consumption but which has other domestic uses.

6.3.3. WaterMark Certification Scheme

All the water supply plumbing pipes and fittings used in plumbing installations in Australia must comply with the mandatory WMCS testing regime. Only WMCS certified products can be used.

The WMCS is a mandatory scheme to certify that plumbing and drainage products are fit for purpose and authorised for use in plumbing installations. The PCA requires certain plumbing and drainage materials and products to be certified by this scheme.

In order to achieve WaterMark Certification, a product or material must:

- be tested by a registered testing authority;
- comply with an approved specification;
- be manufactured in accordance with an approved Quality Assurance Program; and
- carry a warranty.

6.3.4. AS 3688-2005: Water supply – metallic fittings and end connectors

The WMCS references *AS 3688-2005: Water supply – Metallic fittings and end connectors* to set minimum requirements for copper alloy components (brass). Under this standard the allowable level of lead within copper alloy components is less than 4.5 per cent by weight. The lead content makes the alloy more malleable in the machining process.

6.3.5. Australian Drinking Water Guidelines

The ADWG were developed by the National Health and Medical Research Council as a framework to ensure water safety at point of use. The ADWG define safe, good quality water and how it can be achieved.

The ADWG provides limits for specific contaminants that can be allowed in drinking water at its point of use. The ADWG set the maximum allowable concentration of lead at 0.01mg/L. The numerical guideline values for lead in the ADWG are rounded to a single significant figure.[3]

The ADWG are not mandatory standards; however, they provide a basis for determining the quality of water to be supplied to consumers in Australia. Water quality will vary depending on regional or local factors, and economic, political and cultural issues, including customer expectations and willingness and ability to pay.

The Department of Health's *Western Australian Health Facility Guidelines for Engineering Services 2006* requires that hot and cold drinking water for general purposes comply with AS/NZS 3500 and the ADWG.

6.3.6. The *Health (Miscellaneous Provisions) Act 1911*

The *Health (Miscellaneous Provisions) Act 1911* empowers the Chief Health Officer to close a source of water which is not fit for human consumption.

6.3.7. PCH contractual requirements

The PCH contract set requirements for the type of pipework, fixtures and fittings to be installed into the building. Examples of this include the selection of:

- stainless steel piping;
- high-density, cross-linked polyethylene piping;
- dezincification resistant brass (DZR) fittings;
- brass water meters;
- bronze, large-bore isolation valves;
- brass isolation valves;
- chromium plated brass tapware; and
- filtration systems and pump sets.

The hydraulic specification prepared by NDY for John Holland requires compliance with the Western Australian Health Facility Guidelines for Engineering Services for the 'domestic potable cold water treatment system'.

[3] Australian Drinking Water Guidelines (2016, p. 88)

6.4. Lead contamination

In May 2016 lead levels above the ADWG were found in water samples from the PCH. Water was initially tested after Strategic Projects expressed concern that the flushing regime was insufficient and that microbial growth may be occurring.

The Building Commission has reviewed an extensive range of test results commissioned by John Holland, Christopher Contracting, Strategic Projects and NMHS to identify potential sources and causes of lead contamination at the PCH. The Building Commission also reviewed tests for other water chemistry and quality measures, including water alkalinity, softness, micro-bacterial content and other metals.

This section discusses:

- potential causes and sources of lead contamination in the drinking water supply;
- recommended further actions; and
- whether John Holland and Christopher Contacting have met their requirements and responsibilities under the Building Act and the Plumbers Licensing and Plumbing Standards Regulations 2000.

6.4.1. Findings

Testing drinking water for the presence of metals in samples taken from end-use taps and fittings is rarely done in Australia. There are no comparable studies from similar buildings to indicate what “normal” results would be expected from testing for lead.

The PCH and QEII test results available to the Building Commission do not contain coherent time, location and sequence information to allow the Building Commission to determine the source or sources of excess lead. The testing has allowed potential sources of lead to be identified but not the contribution, if any, of each source to the total lead detected in the tests. A coherent strategic and forensic testing regime would have allowed John Holland, Christopher Contracting and Strategic Projects to identify where the excess lead is coming from and to determine appropriate remedial work.

A strategic forensic analysis of chemical signatures in water is necessary to identify the source or sources of lead. Once the source(s) are identified, remediation works can be targeted and completed.

The audit identified the following potential sources of lead contamination:

1. Lead leaching from fittings in the ring main (fire hydrants, etc.).
2. Lead contained in residues in the ring main (including the dead leg).
3. Lead leaching from fittings in PCH plumbing (brass fittings and taps, etc.).
4. Lead contained in residues in the PCH water supply network (residues containing lead from PCH brass fittings, residues drawn in from the QEII ring main).

The Building Commission considered the effect of dezincification on brass valves and fittings that were otherwise compliant, arising from water quality issues associated with:

- chlorine balance of the PCH water;
- dormant water in the PCH water supply system; and
- soft water supplied from the scheme water.

An assessment of the effect of lead contamination in the water at PCH on construction workers has been undertaken by Ecosafe International (Ecosafe). A summary of its findings is included in section 6.4.2.5.

6.4.1.1. Sources and causes of the lead contamination

The Building Commission has reviewed a significant amount of documentation that has been used by Strategic Projects, John Holland and other parties to identify potential sources and causes of lead contamination at the PCH.

Water quality is regulated by the Chief Health Officer of the Department of Health. The regulator's role and powers in relation to water quality at the PCH do not come into effect until after practical completion. The Building Commission cannot make a determination that the lead levels in the hospital drinking water are safe.

The Building Commission examined the potential sources of the excess lead (*where* the lead may be coming from) and the likely causes (*why* the lead is entering the water supply).

6.4.1.2. Possible sources of lead contamination

Water Corporation scheme water

The Water Corporation scheme water has consistently shown negligible presence of lead. The Building Commission therefore does not consider it a potential source of the lead contamination.

Water Corporation testing, including additional sample points closer to PCH after the presence of lead was known, showed negligible lead content. These results were checked against the normal (six monthly) sampling regime which also showed negligible lead. Some sample points were at the most hydraulically disadvantaged points in the Mount Eliza network, meaning the water has further to travel and could concentrate any impurities present. The new and existing test points closer to PCH were compared to the distant points with the same outcome, being negligible lead.

QEII ring main fittings

The QEII ring main could contain brass fittings, soldered joints and galvanised pipes that contain lead. Brass fire hydrants connected to galvanised steel riser stand pipes are also a possible source of lead.

Hardness in water allows a stable scale coating to form within pipes and pipe fittings that inhibits the leaching of metals, including lead, into the water. The age of the QEII ring main suggests that a scale coating has formed and the Building Commission considers that these fittings only contribute minor or negligible quantities of lead to water flowing to the PCH. This is supported by tests taken by NMHS from the QEII ring main and attached buildings that almost exclusively showed lead levels below ADWG guidelines.

QEII ring main residues

Water quality tests in the QEII ring main have shown intermittent and isolated results for lead contamination above the ADWG guideline value of 0.01mg/L. Residues from the ring main's dead leg have also returned test results with significant levels of contaminants including lead. As such, the Building Commission considers that residues in the QEII ring main are a possible source of the lead measured at endpoint tests at the PCH.

The Building Commission considers that residues in the QEII ring main may have been disturbed by fluctuating water flows at the time of the initial connection to the PCH and charging of the system and transported into the PCH plumbing network.

PCH fittings

Brass fittings installed in PCH were tested and found to contain lead levels that are in accordance with the PCA. However, the tested brass fittings also show signs of dezincification which can expose lead, allowing it to leach into the water supply. The Building Commission considers this leaching is a possible source of the lead measured at endpoint tests at the PCH.

PCH residues

Lead leached from brass fittings installed in the PCH may have formed residues, particularly at times of low or dormant water flow. There was some debris found in the PCH plumbing system which may have trapped lead and residues containing lead, including residues drawn in from the QEII ring main (see section 6.4.1.10). The Building Commission considers that these residues are a possible source of the lead measured at endpoint tests at the PCH.

6.4.1.3. Temporary PCH site water

The temporary water supply to the PCH construction site was sourced from two independent temporary water services. One supply came from the QEII ring main on Hospital Avenue a little to the north of the new PCH. The other was connected directly to the Water Corporation supply on Monash Avenue. This water was used in the site offices and facilities, and for the construction works.

Christopher Contracting provided evidence that testing by ALS on 1 September 2016 on the water supply from the QEII ring main on Hospital Avenue returned elevated levels of lead on the inlet side of the filter housing and trapped within the water filter material.

6.4.1.4. Brass fire hydrants with galvanised riser pipes

Building Commission plumbing inspectors observed a significant number of fire hydrants connected to the QEII ring main. Many of the hydrants have galvanised stand-pipes. Galvanizing involves applying a zinc coating to the surface of a metal product to protect it from corrosion.

A small amount of lead is commonly added to galvanizing baths and there is evidence that galvanised coatings may contain lead that can leach into water. Therefore the Building Commission considers that the fire hydrant stand pipes connected to the ring main may be a source of lead contamination for the QEII Medical Centre.

Galvanised pipework is considered safe to transport water, but under the current AS/NZS 3500:2015 it is not suitable to be installed in a drinking water service. Contaminants may leach into the water, especially if the water is corrosive.

The hydrants are effectively dead legs as they are charged with water but have little or no flow when not in use. Where there is no backflow protection, water in the hydrants can be drawn down or back into the ring main, especially during variable flows or when water demand exceeds the ring main's supply capacity. The dormant water in the hydrants could corrode the galvanised coating and therefore contain raised lead levels, which could be transported back into the ring main.

The PCA requires all products and materials in contact with drinking water be certified to *AS/NZS 4020:2005 Testing of products in contact with drinking water* and be certified in accordance with the WMCS.

6.4.1.5. *Lack of scour valves in QEII ring main*

The Building Commission was informed by NMHS that the ring main did not contain any scour valves. A scour valve is installed to clean the base of a large water pipe, allowing sediment to be drained or flushed away. The lack of scour valves suggests that residues that might build up within the QEII ring main have not been removed as part of routine maintenance.

Evidence from the two QEII water meters, where the scheme water enters the QEII ring main, indicates that the water flow within the ring main has been unbalanced. Figure 4 shows that for some time most of the water flow was from the north water mains connection.

The Building Commission considers that the unbalanced and low water flows in the QEII ring main may have allowed sediment and contaminates to accumulate. The lack of scour valves means the ring main cannot be easily flushed out.

6.4.1.6. *Metallurgy*

Brass is an alloy of copper and zinc with small quantities of other metals, often including lead. *AS 3688-2005: Water supply – Metallic fittings and end connectors* requires fixtures coming into contact with water drinking to have a lead content of less than 4.5 per cent.

The allowable level of lead in brass fittings has been shown in normal circumstances not to leach lead at levels that exceed 0.01mg/L, as allowed by the ADWG. Project documentation and tests viewed by the Building Commission suggest the brass fittings in the PCH meet the required levels in the Australian Standards. Similar fittings have been used in other construction projects. The Building Commission is not aware of any similar issues reported with the use of brass fittings in other Western Australian buildings. However, while plumbing systems in new buildings are customarily tested for microbes and bacteria, metal content testing is rare in Australia.

Brass can react with hardness in water to allow a thin, stable, non-metallic coating to form on the inside of pipes and fittings. This coating can prevent or reduce corrosion of the metal and therefore prevent metals leaching into the water. It takes some time for this coating to develop, so water from brand new plumbing installations is likely to have a higher metal content than that from older plumbing systems.

6.4.1.7. *Water quality*

A number of water quality factors can affect the rate that lead leaches from brass fittings, including:

- high levels of carbon dioxide, oxygen and chlorine;
- mildly acid or alkaline conditions;
- dormant or low velocity waters;
- permeable deposits on the tube (pipe) surface;
- higher temperatures;
- high chlorine ion concentration;
- low salt content; and
- soft water.

Water Corporation scheme water supply

Three Building Commission officers met with a Water Corporation representative to discuss the quality, flow, chemistry and testing of the scheme water entering the QEII ring main. The Water Corporation later provided test results to the Building Commission that indicate the quality of water supplied to the QEII ring main is within the ADWG (see Table 2).

Table 2: Water Corporation test results for lead content in scheme water at QEII

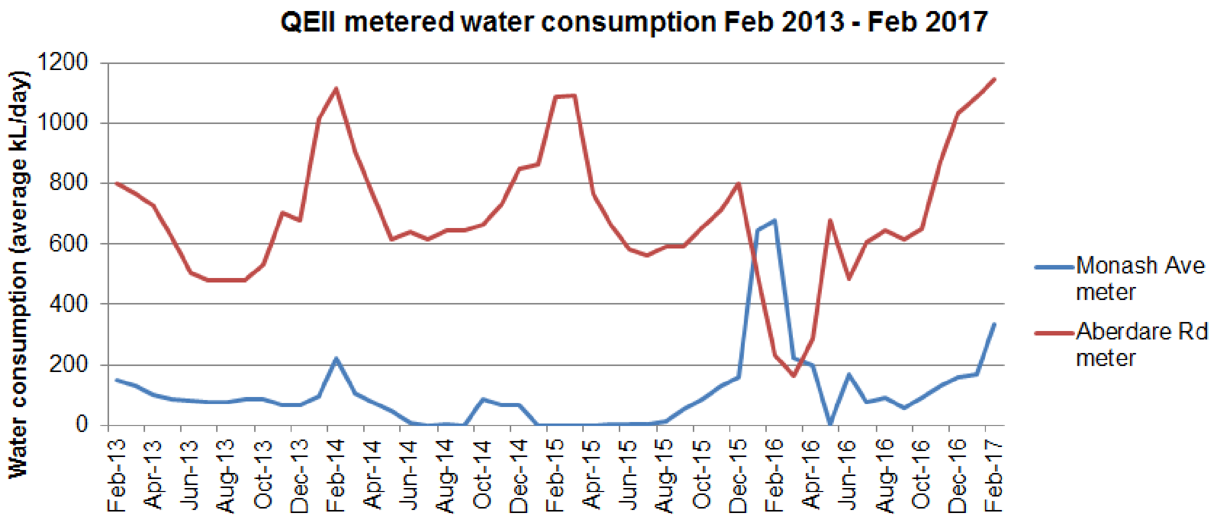
Monitoring Point	Reading Date	Lead (mg/L)
SP Swanbourne North St	23/10/2013	<0.002
SP Swanbourne North St	22/10/2014	<0.002
SP Swanbourne North St	22/10/2015	<0.002
SP Swanbourne North St	21/10/2015	<0.002
SP Subiaco Tighe St	06/09/2016	<0.002
SP Swanbourne North St	07/09/2016	<0.002
SP Monash Ave/Hampden Rd	09/09/2016	<0.002
SP Aberdare Rd/Hospital Ave	09/09/2016	<0.002
SP Swanbourne North St	26/10/2016	<0.002
SP Swanbourne North St	18/01/2017	<0.002
SP Monash Ave/Hampden Rd	25/01/2017	<0.002
SP Aberdare Rd/Hospital Ave	25/01/2017	<0.002
SP Monash Ave/Hampden Rd	13/02/2017	<0.002
SP Aberdare Rd/Hospital Ave	13/02/2017	<0.002
SP Monash Ave/Hampden Rd	13/03/2017	<0.002
SP Aberdare Rd/Hospital Ave	13/03/2017	<0.002

At this meeting the Water Corporation further advised that when they became aware of the presence of lead in the PCH water supply, the Water Corporation tested the scheme water feeding into the QEII Medical Centre by installing test points at the meters feeding the QEII site, one of which is not far from the PCH. All test results were negative for lead at this time and have continued to be so.

QEII ring main water flows

Flow data for QEII ring main provided by the Water Corporation showed that the southern water supply (Monash Ave) of the QEII ring main was subjected to lower flows of water for an extended period. Almost all the water used in the QEII ring main in 2015 was drawn from the northern (Aberdare Rd) connection. However, in the last months of 2015 the amount of water drawn from the southern connection steadily increased, peaking in early 2016 during the commissioning of the PCH (see Figure 4).

Figure 4: Comparative water flow through the north and south meters into the QEII ring main. (Data supplied by the Water Corporation.)



The increased and variable water flow in this previously low flowing section of the ring main (which contains the dead leg) may have disturbed any residues present in the pipe, allowing them to be drawn into the PCH water supply system.

Low flow events in the QEII ring main

A low flow event occurs when the demand for water exceeds the volume that the ring main can deliver. Low flow events can cause a vacuum and abnormal water flows, disturbing residues and allowing them to be drawn into the PCH water supply system.

Documentation provided by Christopher Contracting identified a series of low flow events and pressure fluctuations during PCH construction and commissioning works. Two low flow events were attributed to the filling of drinking water storage tanks in the PCH, on 21 January and 17 February 2016.

Two further low flow events occurred on 9 February and 29 July 2016. Both of these events occurred while the DFES was testing the fire systems at PCH. The first test was unsuccessful as the water supply was not sufficient to safely extinguish fires – the low flow resulting in a localised pressure drop and causing the suction hose to become ineffective. The second low flow event occurred during the second DFES fire system test this was attributed to the PCH back up pumps activating and therefore interfering with the DFES appliance own boosting system and causing a localised pressure drop.

DFES undertook a third test on 15 August 2016 which it determined to be successful. This did not result in a low flow event such as described above. However, it would have drawn a substantial quantity of water from the ring main affecting normal flows.

The Building Commission has seen evidence of other low flow events on dates that coincided with system flushing, replacement of stainless steel pipes, replacement of valves and the dead leg disconnection.

Water Corporation feed upgrade

Subsequent to the failed fire service test on the 9 February 2016, the Water Corporation upgraded the North and South feeds to the QEII ring main:

- South Meter changed from 100mm to 150mm supply meter on 16 May 2016.
- North Meter changed from 100mm to 150mm supply meter on 15 April 2016.

This upgrade was planned by NDY as part of establishing the PCH and this suggests that the original system was not capable of supplying water to meet DFES firefighting requirements. The upgrade in water meter size increased the volume of water from the Water Corporation southern feed into the QEII ring main. The Building Commission considers that this change in flow may have disturbed residues within QEII ring main and allowed them to be drawn into the PCH plumbing system.

Ring main water quality testing

On 14 October 2016 the Building Commission in conjunction with NMHS tested water from the QEII ring main for lead and water softness. The Building Commission plumbing inspectors identified locations for water samples to be collected and ChemCentre was engaged to carry out the testing.

Two out of the ten samples taken had lead levels above the ADWG limit of 0.01mg/L. The test sample from the west side of D block had a total lead level of 0.022mg/L and test sample from the south side of F block had a total lead level of 0.011mg/L.

All 10 test samples had calcium carbonate levels within the range for soft water. Soft water is known to be a factor in the dezincification of brass fittings; this can expose lead, which potentially either leaches into the water supply or is released as particulate matter.

John Holland has conducted its own tests on lead content of the water supply from the ring main. The Building Commission has viewed these test results. They showed that the majority of readings were below the ADWG limits; however, there were intermittent readings for lead above the ADWG limits.

Disconnection and testing of the dead leg

In early September 2016 as part of the Building Commissioner's role in auditing the PCH, the Building Commission became aware of the presence of the dead leg, which was dormant since 1969 allowing sediment and bacteria to build up (see photographs 7 and 8). Section 6.2.1 has more information on the dead leg. This section of pipe was installed to allow for future expansion of the QEII campus facilities.

The management of dead legs is not covered in the PCA, however, they are known to harbour bacteria by allowing biofilms to develop.

The Building Commission recommended that Strategic Projects remove the dead leg as a matter of priority. The dead leg was then disconnected on 29 September 2016. Water samples were collected by ALS Environmental, which was engaged by Christopher Contracting, and ChemCentre which was engaged by Strategic Projects.

ChemCentre took eight samples within the dead leg and only tested for lead and not for any other contaminants. The results provided a large range in lead levels, with the lowest being 0.0012mg/L, for test two described as 'QEII main dead leg 1st sample', and the highest result being 0.36mg/L, for test seven, described as 'end of dead leg 50m'. Test three provided the second highest result at 0.062mg/L taken from the dead leg 'sludge'. As stated previously, the maximum level for lead under the ADWG is 0.01mg/L to one significant figure.

ALS Environmental tested for a total of nine metals, including lead. There were seven tests taken in the dead leg. The ALS results found high lead levels, and also higher-than-permitted levels of cadmium, copper, nickel, manganese and iron, as well as biofilm and microbiological organisms. Of the nine metals tested for, six exceeded ADWG limits, in some cases by a significant amount (see Table 3).

Table 3: Test results for metal content of dead leg water, compared to ADWG limits

Metal content in QEII dead leg water compared to ADWG limits			
Metal	QEII dead leg (mg/L)	ADWG limit (mg/L)	Variation
Arsenic	0.004	0.01	40%
Cadmium	0.0048	0.002	240%
Chromium	0.034	0.05	68%
Copper	14	2	700%
Nickel	0.137	0.02	685%
Lead	0.282	0.01	2820%
Zinc	1.37	3	46%
Manganese	23.1	0.5	4620%
Iron	159	0.3	53000%

Note: Some of these ADWG limits are set for aesthetic, rather than health, reasons.

Photographs 7 (left) and 8 (right): Inside the QEII ring main 'dead leg'

To enable future testing of the ring main water at that point, the Building Commission plumbing inspectors recommended the installation of a flushing/testing valve. Only the testing valve was installed.

The relative concentrations of metals in the dead leg could represent a characteristic signature of residues generally within the QEII ring main. End point testing within the PCH generally did not measure metal content other than lead. Therefore the Building Commission cannot assess the relative contribution of lead from residues drawn from the QEII ring main to excess lead in end point test results.

6.4.1.8. Commissioning the water supply

Christopher Contracting gave the Building Commission documentary evidence of its commissioning process.

The PCA requires water supply systems, water storage tanks and drinking water services to be flushed and commissioned in accordance with *AS/NZS 3500.1:2015 Plumbing and drainage – Water services*. Under the contract John Holland was responsible for compliance and engaged Christopher Contracting to fulfil this requirement. NDY provided Christopher Contracting with specifications that detailed the commissioning process.

Chlorine is commonly used as a disinfectant to treat scheme water; the ADWG note that chlorine is typically added to drinking water in concentrations of 2–3mg/L. AS/NZS 3500.1:2015 requires that water in storage tanks and service pipes be disinfected by adding chlorine to achieve at least 10mg/L of water, for not less than six hours, followed by flushing.

Heavily chlorinated water must not be left for prolonged periods as it can damage internal pipe surfaces or corrode the pipe. At the end of six hours, the chlorinated water must be flushed from the system until chlorine measurements showed that the concentration in the water leaving the system was no higher than 5mg/L, the level permitted in scheme water.

Christopher Contracting undertook the required commissioning on 9 January 2016. The commissioning involved disinfecting the plumbing network with chlorine and then flushing.

Flushing

Christopher Contracting provided documentation to the Building Commission showing that the PCH's drinking water supply network was charged and flushed with water from the QEII ring main from the north feed on 5 February 2015 and then charged and flushed from the south feed on 19 March 2015. This flushing did not involve chlorination. The documentation does not contain a record of further flushing of the system until the first confirmed system flush on 9 January 2016 when the system was disinfected and cleansed with chlorine. There was a period of nearly a year where there was minimal usage and therefore water flows through the PCH plumbing system, leading to dormant water in parts of the system.

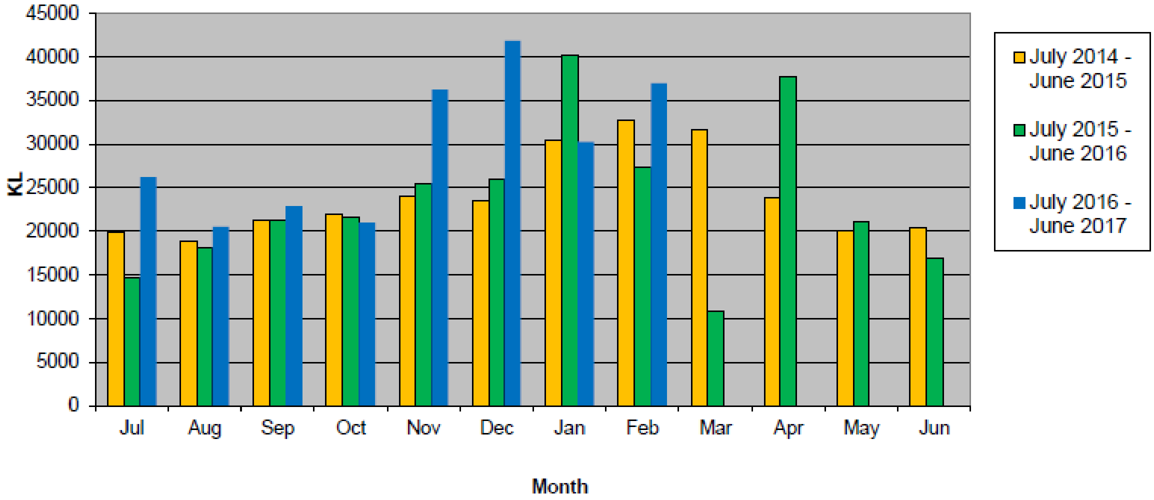
The project hydraulic specifications by NDY and AS3500 Appendix I and J are silent in relation to ongoing flushing at PCH once the initial disinfection flush and testings were undertaken.

The Building Commission observes however that it is well known that large water systems require through-puts of water to prevent microbial build ups and other related problems, or the system after initial testing should be drained and dried out until ready for use then recommissioned. Christopher Contracting advised that after the discovery of lead in the water supply in May 2016 it undertook extensive additional flushing in an attempt to reduce the lead levels.

NMHS provided the Building Commission with data from the invoice from the Water Corporation showing the levels of water usage for the past three financial years. These figures potentially show the increase in water use that would be expected when an extensive flushing program is commenced (see Figure 5).

However, the monthly readings for the whole QEII Medical Centre may not be a clear indicator of a flushing regime as a single flush of the PCH would use approximately 450kL compared to a total monthly consumption of between 15,000 and 40,000kL.

Figure 5: QEII Medical Centre water consumption 2014–2015, 2015–2016 and 2016–2017



6.4.1.9. Construction contamination

When installing new plumbing systems on large construction sites it is possible for dirt, debris and other contaminants to enter the pipe network. The PCA sets out commissioning requirements to remove any contaminants including flushing the pipes with water, and sterilisation by treating the water with chlorine. The Building Commission has been provided with video camera footage of the internal stainless pipe network at the PCH. This footage shows the presence of swarf, filings and debris. The footage revealed pipe ends were burred (left with jagged or rough edges) and swarf had become trapped on these rough edges, contrary to the requirements of AS/NZS 3500.1.

In December 2016 Zedcon released a report on the PCH drinking water system which was discussed at a PCH stakeholder meeting on 21 December 2016. The report states that:

> '*laboratory analyses of the iron sludge and debris have found highly elevated lead concentrations within the solids which indicates that this material has "absorbed" mobile lead within the water stream and it is now likely to be slowly liberating lead back into the water. This is likely to explain the fluctuating lead levels being observed at any particular outlet.*'

The Building Commission considers it likely that lead-containing residues had accumulated in the debris at low points and at the crimped joints of the stainless steel pipes. The commissioning process and additional flushing had been unable to completely remove this debris. As the water flows over the debris there is potential for the lead to be reabsorbed into the water, potentially explaining the intermittent and inconsistent positive results for lead.

6.4.1.10. Plumbing fittings in contact with drinking water

A potential cause of lead contamination at the PCH is from fixtures and fittings, including pipework, in contact with the water. The Building Commission examined the compliance of these elements of the plumbing network.

Certification documents for plumbing fixtures and fittings

The Building Commission obtained and reviewed certification documents for components of the plumbing installation. The documentation included approximately 60 WaterMark and conformance certificates, and associated product schedules listing individual fixtures and fittings.

The certificates provided evidence of conformity with the WaterMark Certification Scheme (WMCS) and compliance with *AS 4020 – Products in Contact with Drinking Water*.

The only component used that did not meet WaterMark certification requirements was the replacement 168.3mm diameter stainless steel piping (see section 6.5). This does not contain lead.

Tests on polymer plumbing fittings

Testing was carried out by ChemCentre on polymer piping installed in the plumbing system to determine if lead was present in the composition of the pipes. These tests results showed no lead.

6.4.1.11. Lead leaching in brass alloys

Lead can leach from brass in contact with water. The amount of lead leached into water from a brass fitting depends on the rate at which the water flows through the fitting. More lead will be found in water that has remained stagnant in contact with brad than in flowing water that has less contact time.

The PCA permits brass alloy valves and fittings to have a lead content of below 4.5 per cent. Metallurgical testing was undertaken on selected plumbing products installed in PCH, including tapware, thermostatic mixing valves, T-pieces and elbows.

Destructive tests on the brass fittings were done by Curtin Corrosion Engineering Industry Centre (CCEIC). The test results reviewed by the Building Commission show the lead contained in the brass products to be well within the limits permitted by the WMCS.

6.4.1.12. Dezincification of brass plumbing fixtures and fittings

The Building Commission has been provided with test reports from Jacobs, CCEIC and Zedcon that all identify dezincification in sample brass fittings removed from the plumbing systems within the PCH.

Dezincification is a form of corrosion in which zinc is dissolved out of a brass alloy. This exposes lead from the affected brass, allowing lead to leach more easily into the water supply that from brass that has not been corroded.

CCEIC found that the brass fittings it tested had evidence of dezincification. This dezincification, combined with the presence of lead and zinc found in the water at the PCH, indicates that the brass fittings are a source of the lead in the water. The CCEIC's report concluded that:

> *'…the presence of dissolved lead and zinc in the potable water taken from PCH indicate that the source of dissolved lead is the brass. In the authors opinion the problem of dezincification and lead contamination can be attributed to stagnant water…'*

The Jacobs report commissioned by Strategic Projects attributes the lead contamination to lead leaching and dezincification of the brass fittings. It found the leaching and dezincification most likely occurred through a combination of Alkaline waters, increased water temperature during commissioning and dormant or low flow water. The report states that leaching will occur from pipework and fittings in the early life of a new system, prior to protective oxide films forming.

The Zedcon report commissioned by John Holland states that laboratory investigations of used brass fittings taken from the drinking water supply system at PCH detected signs of dezincification and a likelihood that some lead release had occurred. Laboratory testing found there was no lead extraction deeper than six microns. The Zedcon report did not examine lead from residues in the pipework, nor provide any analysis to demonstrate that the total lead as measured in tests could have come entirely from the brass fittings.

6.4.1.13. Most likely causes of lead contamination

Disturbed residues in the QEII ring main

The now-disconnected dead leg of the QEII ring main contained built-up residue that when tested was found to contain elevated levels of lead and other metals. This indicates that similar metals could be found in residues elsewhere in the QEII ring main.

The Building Commission considers it likely that variable water flows associated with commissioning the PCH plumbing system and testing undertaken by DFES (see section 6.4.1.8) have disturbed residues in the QEII ring main which were then drawn into the PCH plumbing system.

Test results taken by NMHS from the ring main showed sporadic excessive lead levels. Test results taken by John Holland from the feeds into PCH showed sporadic excessive lead levels. If residues were only significantly disturbed at times of variable water flows directed towards the PCH, excess lead readings would not necessarily be detected in water tests taken at other times or in other buildings connected to the ring main.

Lead leaching and dezincification in brass fittings in PCH

Lead contained in the brass fittings in PCH will have leached into water flowing through the fittings. The rate of leaching is likely to have increased as a result of dezincification. Although there is no definitive explanation for the dezincification, potential causes include:

- long periods of dormant water in the plumbing system;
- over chlorination; and
- water chemistry, including the softness of the water.

Water in the PCH plumbing system remained substantially dormant between March 2015 and January 2016. The Building Commission considers that this may have generated conditions favourable for dezincification.

The Building Commission has not seen test results or other documentation to demonstrate over-chlorination. There are not enough test results of chlorine levels taken since the PCH plumbing system was charged with water to allow the Building Commission to conclusively exclude over-chlorination as a possible cause of dezincification.

Water Corporation data indicate that the scheme water feeding the QEII ring main tends to be moderately soft. However the Building Commission considers this degree of softness is unlikely to account for the level of dezincification seen in PCH brass fittings. No reports available to the Building Commission suggest that softness in scheme water is the cause of the dezincification of brass fittings at PCH, and hence the release of excessive lead.

Lead released into water by dezincification of brass fittings within the PCH may have remained in the water and been directly detected in end-point testing, or may have been incorporated into residues and subsequently been reabsorbed into the water and then detected in end-point tests.

If the excess lead is predominantly coming directly from the brass fittings in the PCH, more consistent excess lead results would be expected at each end point. Because the testing regime does not control for consistent water flows it is possible that variation could result from water remaining dormant in the fittings for varying periods. This might account for varying test results. Alternatively, the sporadic detection of excessive lead could be accounted for by varying water flows disturbing the residues within the PCH.

6.4.2. Rectification

6.4.2.1. Water testing

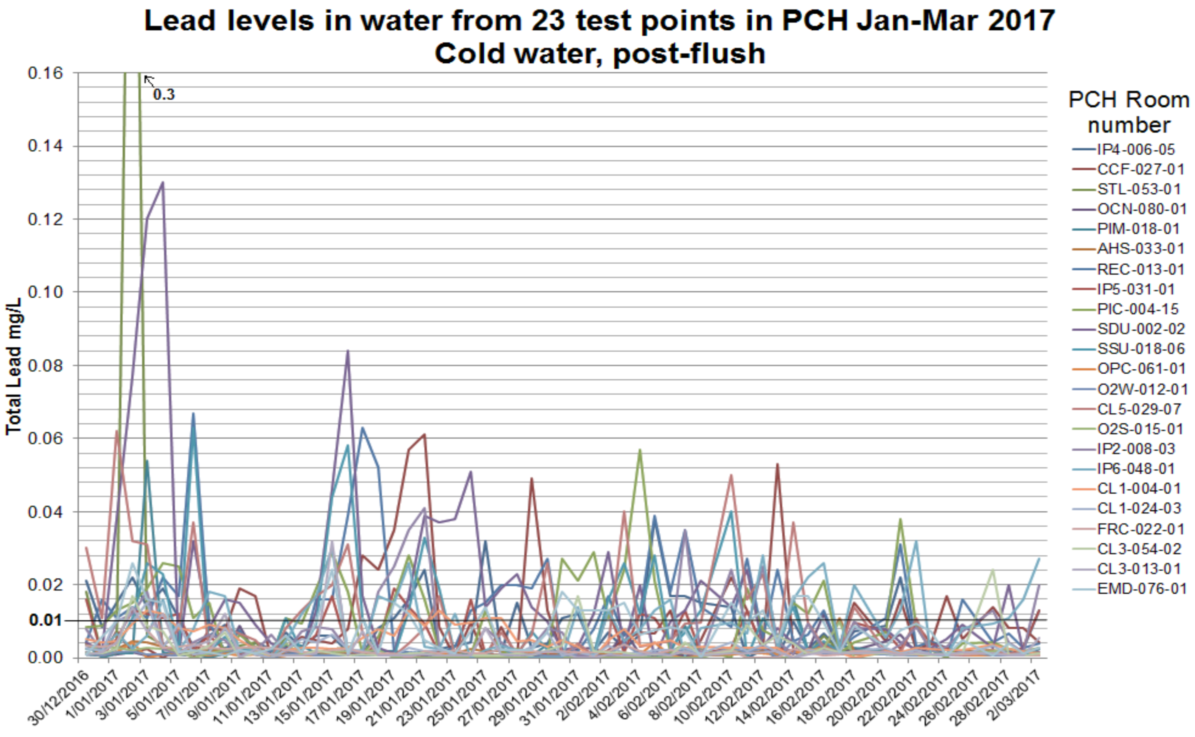
On discovery of lead in the PCH drinking water supply John Holland, Christopher Contracting and Strategic Projects each committed to carry out their own water testing and to share the results with the other stakeholders.

An extensive water testing regime of more than 1,000 individual tests commenced in May 2016. This testing was carried out by a number of laboratories (QED, ChemCentre, Zedcon and ALS). Testing was undertaken at various outlets, at various times of the day, on different days and over a period of months.

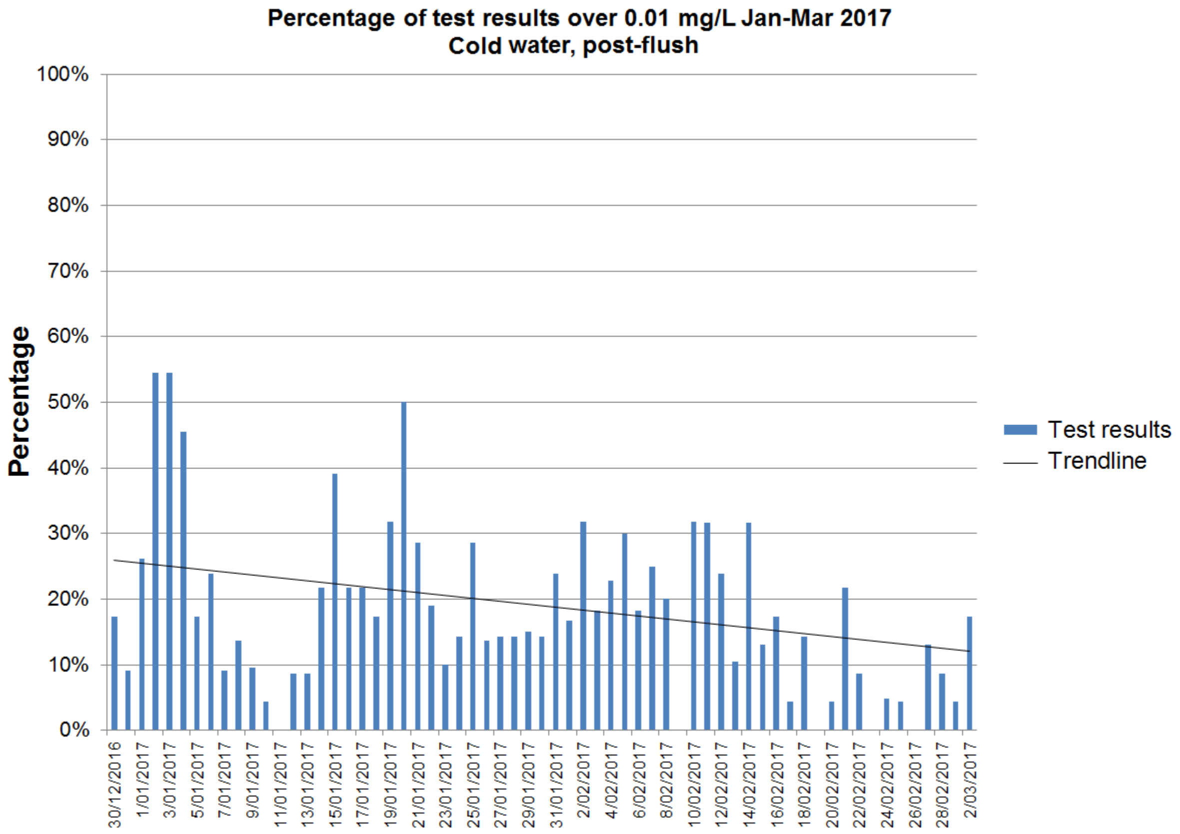
The tests provided readings for dissolved lead and total lead. Higher levels in the total lead readings suggest the presence of particulate lead in the water.

Test results consistently show that lead is present in the water, although variable in its concentration and location. Filters were installed throughout PCH in December 2016 and were operating from mid-January 2017. Test results from January to March 2017 show lead levels in PCH drinking water steadily decreasing, although there are still intermittent readings above the ADWG for lead. More recent test results show higher incidences of lead than the lowest results reported in March 2017.

Graphs 1 to 4 show an indicative selection of the results from a range of testing points at PCH The test results were provided by Strategic Projects.

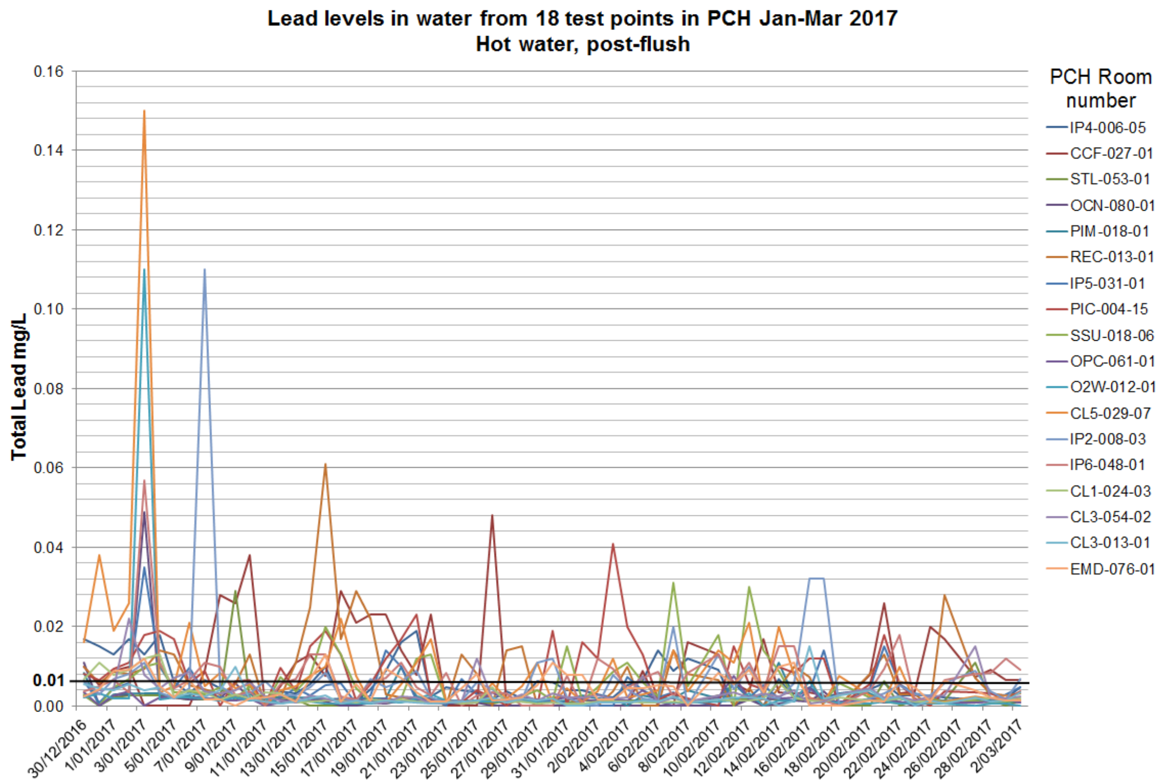


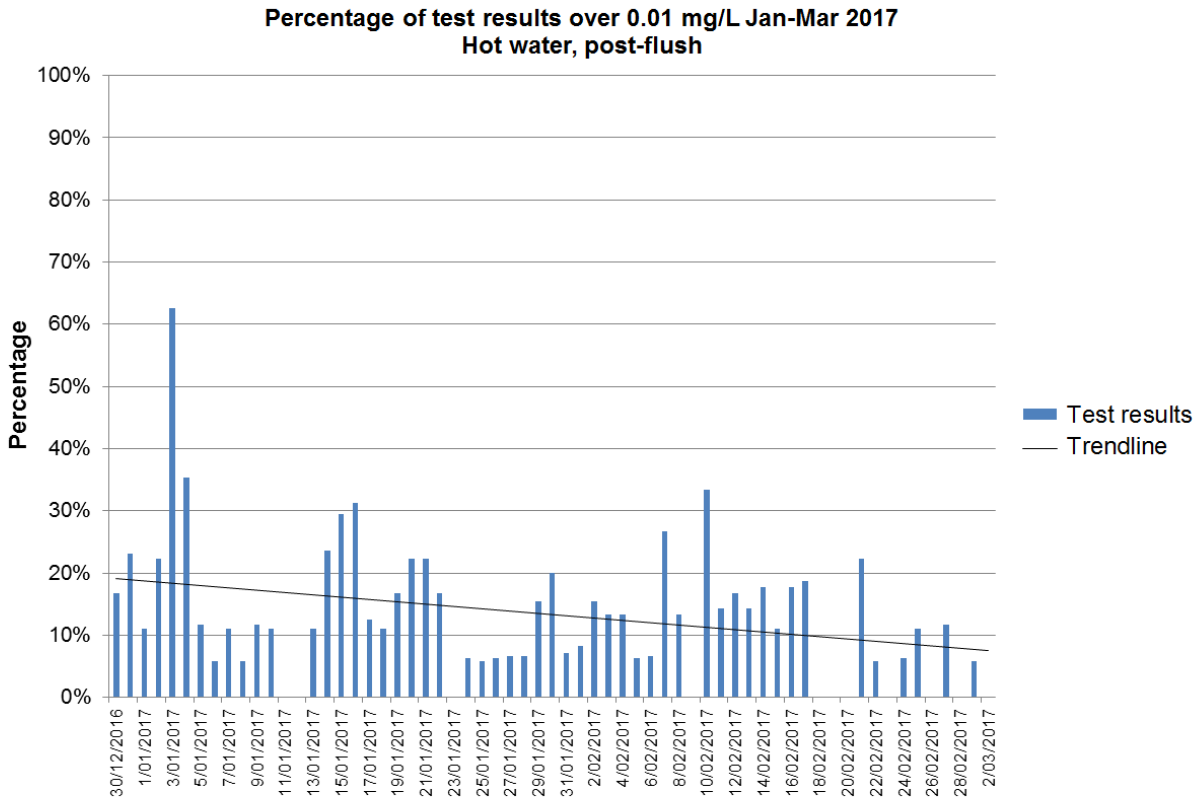
Graph 1: Lead levels in PCH drinking water for January to March 2017, cold water post-flush. The different coloured spikes indicate that high results are appearing intermittently at many different test locations.



Graph 2 (above): Percentage of cold water, post-flush tests showing lead levels over the ADWG limit from January to March 2017

Graph 3 (below): Lead levels in PCH drinking water for January to March 2017, hot water post-flush. Note the different coloured spikes, indicating that high results are appearing intermittently at many different test locations.





Graph 4: Percentage of hot water, post-flush tests showing lead levels over the ADWG limit from January to March 2017

Strategic Projects

Strategic Projects undertook a comprehensive testing program of the PCH water supply system, including tests of brass fittings and polymer pipe for evidence of lead leaching. This testing was carried out between May to August 2016. Strategic Projects contracted QED Environmental Services to undertake the testing program. QED subcontracted laboratory testing to Silliker Australia, MPL, Envirolab, ALS and ChemCentre.

In November 2016, CCEIC was engaged to undertake a corrosion investigation of select brass fittings removed from the drinking water supply system as a possible source of lead.

In December 2016 Jacobs was engaged to assist in identifying the potential source(s) of the lead contamination within the PCH drinking water network. This engagement included a request for options relating to potential solutions in order to achieve the required compliance with the ADWG.

John Holland

On discovering lead in the drinking water supply, John Holland notified Strategic Projects and Christopher Contracting in accordance with their contractual obligations.

John Holland protected its workers by providing bottled drinking water and instructed workers not to drink from the PCH drinking water outlets.

John Holland engaged Ecosafe to develop a sampling, analysis and quality plan for implementation at PCH. The purpose of this work was to determine the extent and severity of lead contamination in hot and cold drinking water distribution systems, as well as to identify the likely cause of the contamination.

John Holland contracted IAQS to undertake the water testing program, which was carried out between July to September 2016. IAQS subcontracted laboratory testing to ARL, Eco Diagnostics and ALS.

Christopher Contracting

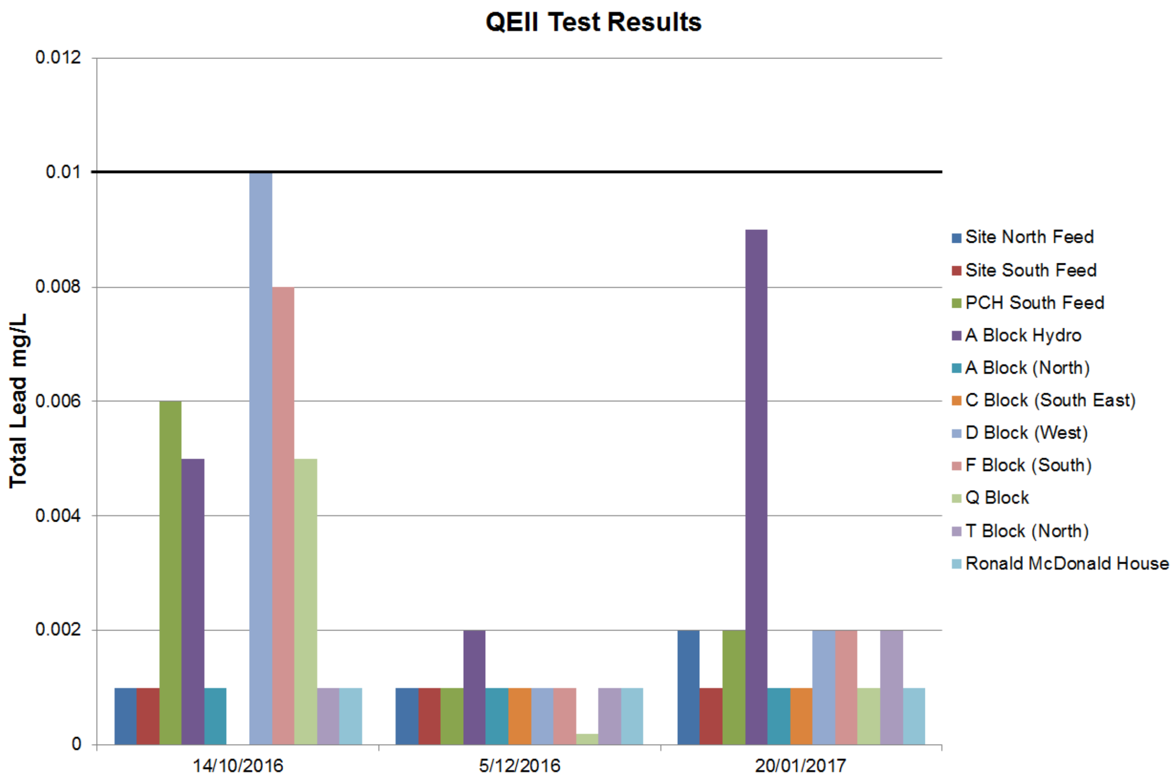
Christopher Contracting's initial water testing formed part of the commissioning program and did not specifically test for lead. On being informed of the discovery of lead in the drinking water supply, Christopher Contracting implemented a water sampling regime to monitor lead levels in the PCH water supply.

Christopher Contracting contracted Extrin to undertake the additional water testing, which was carried out from June 2016 to March 2017. Extrin subcontracted laboratory testing to ALS.

Christopher Contracting continued with extensive water testing, flushing from both the ring main and the Water Corporation main supply, and ultimately the installation of carbon filters.

North Metropolitan Health Service

The NMHS has tested water from 11 locations within the QEII Medical Centre. These results show that lead levels in the water supply are all at or below the allowable limit in the ADWG (see Graph 5).



Graph 5: Lead levels for drinking water at 11 test locations throughout QEII Medical Centre, from October 2016 to January 2017

6.4.2.2. Removal of dead leg

On 29 September 2016 the dead leg was disconnected. During the disconnection process, samples were taken from the dead leg section and analysed by ALS Environmental. The results found higher-than-permitted levels of lead, cadmium, copper, nickel, manganese and iron. The tests also confirmed the presence of biofilm, a mucus-like substance that contains bacteria and microorganisms that potentially affect water chemistry.

6.4.2.3. Stakeholders meeting − 21 December 2016

The Building Commission was invited to a meeting of key stakeholders on 21 December 2016 called to discuss possible rectification works after the release of two reports, one from Jacobs and the other from Zedcon that identified potential causes of the lead contamination. John Holland and Strategic Projects agreed to proceed with the filtering and relevant testing, and to evaluate the results.

The Jacobs report recommended that Strategic Projects undertake a detailed water testing regime, with samples to be taken over two stages from various locations, including a sample point immediately upstream of filtration equipment. ChemCentre provided detailed analysis and reports of all samples.

Zedcon recommended a program of works to continue flushing the system with water from the QEII ring main and to install filters in key locations, including each floor within the PCH. The performance of the filters should be monitored by ongoing water quality analysis to verify lead levels are within the allowable limit and to ensure filter cartridges are replaced as required. The Zedcon report states that under normal operating conditions, the brass fittings are unlikely to cause corrosion or water quality problems and further treatment should not be necessary.

6.4.2.4. Managing lead contamination

John Holland agreed to provide a comprehensive management plan and risk mitigation strategy for the filtration equipment in the basement and risers, for approval by Strategic Projects. The plan included frequency of filter change, maximum water use, number of hours use per filter, pressure differential between filter inlet and outlet, testing of filter debris and reporting mechanisms. It also included an ongoing plan to ensure maintenance and monitoring of the filters will not disrupt operation once the PCH is in use.

The Building Commission considers that the brass fittings and fixtures at PCH are contributing to lead detected in end-point tests, but the test results do not allow the Building Commission to determine the relative amount. It is normal in plumbing installations for brass to leach some lead into water, but at levels below the ADWG. Leaching reduces over time if hardness in the water allows a protective scale coating to form on the brass. The protective coating requires the source water to be sufficiently hard and non-corrosive over a time period of approximately two years.

There are little data available on the potential for compliant plumbing fixtures leaching excessive lead in other applications across Australia. However, an environmental research paper from Macquarie University[4] tested the water from 212 residential plumbing systems in New South Wales, and found that 8 per cent of them exceeded the ADWG level for lead. The report confirmed that tests from water left dormant in a fitting will show higher lead levels than tests from samples taken after flushing.

[4] Widespread copper and lead contamination of household drinking water, New South Wales, Australia; P.J. Harvey, H.K. Handley, M.P. Taylor

In the absence of test results demonstrating that the excessive lead is predominantly being leached from the brass fittings at PCH, the Building Commission does not consider there is a case to remove or replace these fittings. The Building Commission does support the use of orthophosphate treatment to coat the dezincified brass fittings to stop lead leaching from this source and combining with other sources of lead to exceed the ADWG.

The Building Commission considers that the residues and debris in the pipes at PCH are contributing to the elevated lead levels but the test results do not allow the Building Commission to determine the relative amount. The residues are steadily being removed by flushing, filtering and replacing some pipes.

The Building Commission considers that the plumbing system as designed and installed at PCH should be capable of operating without generating excessive lead. The Building Commission does not support the permanent use of filters within the plumbing system to control lead. The filters within the plumbing system should be removed once sufficient residues have been filtered out of the system and lead levels are satisfactory to the Chief Health Officer.

The Building Commission considers that lead in water from the QEII ring main may be contributing to elevated levels of lead in end-point tests at PCH but the test results do not allow the Building Commission to determine the relative amount. There are now filters on the ring main supply as it enters PCH which will prevent some residues from getting in to PCH, although dissolved lead and extremely fine particles might still get in should any remain in the ring main system.

The Building Commission considers that the filters at the north and south tunnel feeds to the basement filters and tank storage on the ring main supply should remain, or the PCH should be connected directly to the Water Corporation supply to eliminate any possibility of excessive lead coming from this source.

6.4.2.5. Effect on site workers

John Holland contracted Ecosafe to assess the potential health risks associated with workers' exposure to lead in drinking water at the PCH site. Ecosafe sub-contracted JBS&G Australia Pty Ltd to undertake the report.

The report assumes a conservatively high rate of water consumption by workers on site – 2L per day for five days a week. Nevertheless, it concludes that the health risk to workers from drinking the water were 'low and acceptable'. It continues:

> *'It may be inferred from the results that the lead concentrations in potable water at the new PCH site can be as high as 0.15mg/L before it is considered to pose a concern to the health of the workers at the site during the construction phase.'*

The report states that most lead contamination test results at PCH that were above the ADWG were below 0.15mg/L. Test results from some outlets were above 0.15mg/L, however these readings were intermittent, and were interspersed with periods where the same outlets were below the 0.15mg/L level.

The report does recommend that further research is required to:

- Better understand the variability of the lead concentrations in the drinking water by continuing to monitor the drinking water, focusing on sampling locations with lead concentrations above 0.1mg/L.
- Identify the presence of pregnant or breastfeeding female workers at the PCH site during the construction phase, and whether these female workers were exposed to drinking water at locations with concentrations above 0.1mg/L.
- Identify and remove the cause(s) of the elevated lead in the drinking water at the PCH site.

At the time of the detection of lead there were some Department of Health staff on site, as well as construction workers. These members of staff may have been exposed to lead through their involvement in commissioning activities as part of the handover process. According to Ecosafe, it is possible that some of the staff consumed the water, although it is likely that they consumed less water than construction workers. As such the health risk for these staff is likely to be lower than, or at most similar to, the 'low and acceptable' risk the construction workers were exposed to.

6.4.3. Conclusion

6.4.3.1. Lead contamination

The potential sources of lead contamination at PCH are:

- fittings, such as hydrants and valves, within the QEII ring main leaching lead directly into the water;
- residues within the QEII ring main transported into the PCH and trapped in the construction debris within the PCH pipework;
- residues generated within PCH from dezincified brass fittings and trapped in the construction debris within the PCH pipework; and
- dezincified brass fittings within PCH leaching lead directly into the water.

6.4.3.2. Reducing lead contamination

Remedial actions undertaken by John Holland to reduce lead contamination to date include:

- disconnection of QEII ring main dead leg;
- installation of filters at point of supply from the ring main to PCH;
- installation of filters on water supply risers throughout PCH;
- installation of flushing valves throughout the PCH;
- replacing brass fittings, strainers and pipework in areas where filtering and flushing have proven to be less effective; and
- flushing the PCH plumbing system through a temporary connection to Water Corporation scheme water.

The rectification works carried out to date have significantly reduced lead contamination in the PCH drinking water, however ongoing tests indicate that the lead levels have not yet consistently reached a level that is satisfactory to the Chief Health Officer.

Further options to manage lead contamination for the PCH include:

- lead coming intermittently from the QEII ring main can be reduced by retaining filters at the point of supply to the PCH;
- lead in residues in the PCH plumbing system can be reduced by filtering, flushing and removal of pipes containing residues;
- lead leaching from brass fittings can be reduced by replacing fittings with lead-free substitutes; and
- lead leaching from brass fittings can be reduced by orthophosphate treatment to coat the dezincified brass fittings.

6.4.3.3. Conduct of the building contractor

The Building Commission has found no test results or documentation to suggest that non-compliant or non-conforming products or installation methods have been used which might cause raised levels of lead in the water.

The Building Commission has insufficient evidence to demonstrate that John Holland took appropriate steps to prevent water stagnation between March 2015 and January 2016.

For workplace safety reasons all John Holland staff, contractors and site visitors were required to drink only bottled water after the lead concern was identified.

6.4.3.4. Conduct of the plumbing contractor

All plumbing requirements for fixtures and fittings that contain lead were satisfactory. Documentation proves compliance with AS/NZS 4020 and compliance with the WMCS.

There is an on-going issue with WaterMark certification of stainless steel pipes, which is addressed in section 6.5. This does not contribute to the lead problem.

The Building Commission has insufficient evidence to demonstrate that Christopher Contracting took appropriate steps to prevent water stagnation between March 2015 and January 2016.

It was impractical to test every individual component installed in the PCH plumbing system, therefore the Building Commission cannot entirely rule out possible product substitution, or the installation of a non-compliant batch. However this is unlikely.

6.5. Stainless steel corrosion

In March 2016, Christopher Contracting identified some corrosion and leaking in the stainless steel piping at the PCH and replaced the affected sections. Sections of the replacement piping corroded within 14 days and were replaced again.

Further investigation by Christopher Contracting identified approximately 60 other areas of corrosion throughout the stainless steel pipework. The corrosion was located mainly at or near the welded pipe seams, with some corrosion on other areas of the internal pipe surface.

Some corrosion was also identified in other stainless steel components of the drinking water supply system, including flanges, filtration equipment and the UV disinfection system.

6.5.1. Findings

The audit identified two potential causes of the corrosion:

- defective manufacturing processes (non-compliant welding or coatings); and
- water quality incompatible with stainless steel.

The audit considered the potential causes of the corrosion of the stainless steel pipes include, but are not limited to:

- defective welding processes for at least some of the stainless steel pipes;
- workmanship associated with the installation of the stainless steel piping system;
- soft scheme water supplied by the Water Corporation to the QEII ring main;
- corrosive water from the dead leg in the QEII ring main water supply system;
- microbially induced corrosion (MIC) transported from the dead leg into the PCH;
- over- or under-chlorination of the PCH water; and
- long periods of dormant water in the plumbing system.

6.5.1.1. Defective manufacturing processes

The stainless steel pipe supplier commissioned Metlabs to report on possible causes of the rust-coloured stains forming on the pipework. The report concluded that ineffective gas shielding during the manufacturing process allowed oxidation to occur which depleted the chromium levels in the pipe joints. Low chromium levels in the welded seams and heat affected zones led to rust stains in these areas caused by corrosion of iron by drinking water.

The Curtin Corrosion Engineering Industry Centre (CCEIC) was also contracted to assess potential causes of corrosion. Their report stated that corrosion of stainless steel pipework for drinking water is related to a combination of factors including temperature, chloride, chlorine and oxygen levels as well as microbial activity.

6.5.1.2. Water chemistry

Scheme water has variable characteristics, depending on the chemical compounds and constituents it contains. These characteristics can be used to assess its quality and safety for drinking. Measureable characteristics of water include:

- physical;
- microbial;
- chemical (inorganic, organic compounds, pesticides); and
- radiological.

It is necessary that water quality be maintained in accordance with the relevant standards, otherwise it may have an adverse effect on the service life of pipes, fixtures and fittings.

Water softness

The softness of the water is a key component of water chemistry and is of particular importance at PCH. The Australian Drinking Water Guidelines [5] note that soft water (<60mg/L calcium carbonate, $CaCO_3$) can possibly be corrosive (see Figure 5).

Figure 6: Extract from the Australian Drinking Water Guidelines – water hardness entry

Characteristic	**Guideline values** (mg/L unless otherwise specified)		**Comments**
	Health	**Aesthetic**	
Hardness (as $CaCO_3$)	Not necessary	200	Caused by calcium and magnesium salts. Hard water is difficult to lather. <60mg/L $CaCO_3$ – soft but possibly corrosive 60-200mg/L $CaCO_3$ – good quality 200-500mg/L $CaCO_3$ – increasing scaling problems >500mg/L $CaCO_3$ – severe scaling

The Building Commission, in conjunction with NMHS, tested the water in the ring main and found that the calcium carbonate levels are generally soft, though variable. Tests in October 2016 returned results between 40 and 58mg/L, which is within the range of soft water. Tests were repeated in December 2016, with results between 24 and 47mg/L. Testing in January 2017 showed the water was between 61 and 75mg/L, slightly above the threshold for soft water.

Chlorination

Table 4 contains Water Corporation data on water alkalinity, hardness and chloride content for scheme water from the Mount Eliza reservoir, which supplies the QEII ring main. The chloride content is the most important parameter because of its influence on localised corrosion. The chloride content is comparatively high, although it is within the ADWG guide of not more than 250mg/L (this limit is based on taste thresholds rather than health considerations).

[5] National Health and Medical Research Council, Australian Drinking Water Guidelines (2011) – Updated November 2016, available at www.nhmrc.gov.au/guidelines-publications/eh52

Table 4: Data from Water Corporation's Drinking Water Quality Annual Report 2015–16 for the Mount Eliza reservoir.

Alkalinity					
Locality	**Samples taken**	**Concentration (mg/L)**			**Guideline met**
		Min	**Max**	**Mean**	
Mount Eliza	2	76	99	88	No guideline value available

Chloride					
Locality	**Samples taken**	**Concentration (mg/L)**			**Guideline met**
		Min	**Max**	**Mean**	
Mount Eliza	2	155	195	175	Yes

Hardness					
Locality	**Samples taken**	**Concentration (mg/L)**			**Guideline met**
		Min	**Max**	**Mean**	
Mount Eliza	2	62	68	65	Yes
Note: These data are given as indicative values. The results are from only two samples, and results can change between sampling dates.					

6.5.1.3. Water Corporation municipal water supply

Water Corporation annual reports indicate that water quality of the scheme water is within the ADWG.

Water Corporation data indicate that the scheme water feeding the QEII ring main tends to be moderately soft. However the Building Commission considers this degree of softness is unlikely to account for the level of corrosion in the stainless steel pipes.

6.5.1.4. QEII ring main

The QEII ring main, including the dead leg, is discussed in sections 6.2, 6.4.1.8 and 6.4.2.2.

The PCH ring main connections are very close to the dead leg (see Photograph 6). Commissioning the PCH plumbing systems increased the water flow in the ring main, which has possibly drawn potentially corrosive water from the dead leg into the PCH.

Water Corporation metering records show that flow rates for the southern section of the QEII ring main were very low until the PCH plumbing systems were commissioned (see Figure 4 and section 6.4.1.8).

The Building Commission considers that the amount of contaminated water in the dead leg is so small in relation to the total amount of water drawn into the PCH that it alone is not a cause of widespread corrosion in the stainless steel pipes. There is no evidence to suggest that the water in the ring main generally is unusually corrosive to stainless steel.

6.5.1.5. PCH plumbing commissioning

The required commissioning process, undertaken by Christopher Contracting, involved disinfecting the plumbing system with chlorine then flushing (see section 6.4.1.9.). Chlorine is corrosive and chlorine overdosing would, combined with high levels of chlorides, reduce stainless steel pipework's passivity. A chlorine overdose in the PCH plumbing network left for a prolonged period of time and not flushed completely could result in corrosion of the stainless steel pipes.

Christopher Contracting provided documentary evidence for the PCH commissioning process stating that the disinfection process was carried out in accordance with the required standard – AS/NZS 3500.1:2015. Christopher Contracting undertook the required commissioning on 9 January 2016.

After the discoveries of corrosion to the pipes and lead in the water Christopher Contracting undertook extensive additional flushing in an attempt to reduce the construction debris and other contaminants that could be contributing to these issues.

6.5.1.6. Inspection of stainless steel pipes

CCTV footage of the internal surface of the stainless steel water supply system was made available to the Building Commission for review. This footage identified areas of corrosion, swarf build up and pipe burring as follows:

- Corrosion was identified on welded seams, at pipe ends, where pipes connect to fittings, on pipe walls and where there was swarf build up.
- Swarf (filings and debris) had collected in various locations throughout the system along the base of pipes near bends, T-pieces and at low points where pipes connect to fittings.
- Burrs (rough or sharp edges left on the pipe by a cutting tool) were identified where pipes had been cut, joined and connected to fittings.

Additional burring and debris may have since occurred during rectification works to install filters and flushing valves, and replace pipes.

6.5.1.7. Certification requirements

The Building Commission audit team carried out an extensive review of all the stainless steel pipes and fittings in the water supply system.

The replacement 168.3mm diameter stainless steel piping did not meet WaterMark certification requirements. The initial 168.3mm piping installed at the PCH was WaterMark certified, but in December 2014 the product was taken off the WMCS schedule.

Building Commission plumbing inspectors issued a Rectification Notice for the product to either regain certification or be replaced with a suitable certified product.

The product has since been re-listed on the WMCS schedule. The administrators of the WaterMark scheme are currently investigating the validity of the product's re-certification.

All other pipes and fittings reviewed met the WaterMark certification requirements and have been used successfully in other construction projects. The Building Commission is not aware of any similar issues with the stainless steel pipes fixtures and fittings used in other buildings.

6.5.2. Rectification

In April 2016 a Metlabs report identified that the welding technique used on the pipes in the manufacturing process was causing the corrosion. Subsequent to this, Christopher Contracting under the direction of John Holland replaced sections of stainless steel pipes.

In May 2016 sections of the corroded 168.3mm stainless steel pipes were replaced. John Holland engaged a consultant for a metallurgy review of the stainless steel pipes, and installed additional valves to bypass any areas of future corrosion, allowing the system to be used after practical completion.

In mid-August 2016 Curtin University (CCIEC) completed a report on the cause of the corrosion which stated that faulty fusion welding of the longitudinal pipe seam was the main issue. Strategic Projects has informed the Building Commission that the pipe is being replaced with an equivalent product that has been tested, confirming that the welding is compliant.

Also at this time Strategic Projects commissioned CCTV technology to inspect the internal condition of the stainless steel pipework. This was done by inserting a camera through selected areas of pipe. This may have introduced further debris into the system.

In mid-November 2016 John Holland advised Strategic Projects that the pipe that services the Central Sterile Supply Department (CSSD) area needed to be replaced due to corrosion.

In early December 2016 CCTV inspections of the stainless steel pipework indicated severe fouling, corrosion, and burrs on poorly installed connections. John Holland again investigated alternative pipe suppliers.

In early January 2017 Strategic Projects received the commissioned report '*Localised corrosion at welds in 316L stainless steel tubing used in the potable water system at the new children's hospital*', authored by Professor Brian Kinsella and Dr Laura Machuca Suarez from Curtin University. This report recommended that seam-welded pipes be installed with the seam located at the top of the pipe, and that alternative pipe materials be considered. Strategic Projects sent the report to John Holland with a formal notice to provide a strategy for the replacement of the remaining corroded stainless steel pipes.

Replacement pipe for the CSSD has been ordered and an installation method and program has been provided to Strategic Projects. Planning works commenced with a meeting on 13 January 2017 to finalise the scope of works and program. This work was completed in February 2017.

Filters were installed on the water supply entering the PCH from the QEII ring main due to the possibility that contaminants in the ring main are contributing to pipe corrosion.

6.5.3. Conclusions

The Building Commission considers the primary cause of corrosion in the stainless steel pipes is defective welding during manufacture. The Building Commission has been unable to establish whether water quality has contributed to the rate of corrosion.

It will require further investigation by water quality and metallurgical experts to determine which, if any, of the causes are contributing to the stainless steel pipe corrosion, and to what extent.

6.5.3.1. Conduct of the building contractor

The Building Commission considers that John Holland undertook all reasonable actions to ensure that the stainless steel pipes within the PCH were compliant. There have been no test results or documentation provided to the Building Commission to suggest that John Holland was responsible for manufacturing defects.

The project hydraulic specifications by NDY and AS3500 Appendix I and J are silent in relation to ongoing flushing at PCH once the initial disinfection flush and testing was undertaken.

The Building Commission notes that water in the PCH plumbing system was dormant between May 2015 and January 2016. The Building Commission notes that large water systems require through puts of water to prevent microbial build ups and other related problems. Alternatively, after initial testing the system should be drained and dried out until ready for use then recommissioned.

6.5.3.2. *Conduct of the plumbing contractor*

The Building Commission considers that Christopher Contracting is not responsible for the manufacturing fault, identified by Metlabs and CCEIC, that contributed to the stainless steel pipes corroding.

However, Christopher Contracting should have taken more care in installing the PCH plumbing system, particularly in relation to the burrs and swarf that the CCTV inspection discovered inside the stainless steel pipework.

The project hydraulic specifications by NDY and AS3500 Appendix I and J are silent in relation to ongoing flushing at PCH once the initial disinfection flush and testing was undertaken.

The Building Commission notes that water in the PCH plumbing system was dormant between May 2015 and January 2016. The Building Commission notes that large water systems require through puts of water to prevent microbial build ups and other related problems. Alternatively, after initial testing the system should be drained and dried out until ready for use then recommissioned.

6.5.3.3. *Managing steel corrosion*

Remedial actions undertaken to manage steel corrosion to date include:

- replacing corroding and defective pipes;
- flushing the plumbing system;
- installing filters to improve water chemistry; and
- installing valves throughout the PCH to allow isolation of sections for future rectification works.

6.6. Burst rubber expansion joint

At about 9.15am on 15 June 2016 an REJ burst in a basement plant room at the PCH. An REJ is a flexible connector of two pieces of pipe.

After the abrupt REJ failure and the subsequent escape of steam and hot water that flooded the plant room, workers immediately informed John Holland of the incident. John Holland closed down the area until an investigation of the cause of the incident was completed.

6.6.1. Findings

Schneider Electric Buildings Australia Pty Ltd (Schneider Electric) was the contractor responsible for the hot water monitoring device, and investigated the incident. The Schneider Electric incident report states that the failure of the expansion joint was due to water entering the coupling at a higher temperature than the REJ was rated for.

The investigation found that *'the facilities (sic) main power supply experiences a temporary interruption every second Wednesday at approx. 7:30am due to generator switching on the main [QEII] campus.'*

The PCH has a Building Management System (BMS) installed. Power to the BMS controller was lost as a result of the generator switching. After power was restored the BMS failed to re-establish a connection to the energy meter which meant that the BMS controller was unable to read the real temperature values of the water. Accordingly the BMS controller kept the temperature control valve open causing the system temperature to climb to 107.3 degrees Celsius.

The system was designed to operate at 70°C. Most components have a maximum rating of 160°C. The REJ was the weakest link, having a rating of 115°C. As such, this was the point of failure when the water exceeded normal running temperatures, causing a loud explosion and a large amount of steam and hot water to be released into the plant room.

Although the BMS reported a temperature of 107.3°C, the temperature at the REJ could have been more or less depending on circumstances. The REJ manufacturer's data guarantees it to withstand temperatures from -30°C through to 115°C.

6.6.2. Rectification

A replacement REJ was ordered from Pacific Hoseflex and installed. The same product was used as John Holland determined that the product had failed only because the water temperature was accidentally heated beyond its tolerance.

To ensure this failure does not happen again:

- mechanical temperature sensors have been installed and are hard wired to shut down the heating water pumps if the water exceeds 70°C;
- an uninterruptable power system (UPS) backup has been installed that will close the temperature control valve when power is interrupted;
- temperature sensors have been installed for a direct connection to the BMS controller; and
- a BMS graphical interface was developed and personnel were made available to monitor the system so that it can be reenergised after mechanical repairs.

6.6.3. Conclusion

The Building Commission has analysed the information provided and concluded that there is no evidence to show that there was any non-compliance or non-conformity of the expansion joint.

The component failure was the result of a control system that was not designed to account for the switching of power sources. However this has now been rectified. The control system failure, caused by generator switching on the main QEII campus, was not planned for in the initial design of the control system.

The rectification measures are sufficient to ensure that the incident will not recur.

7. Fire safety

7.1. Introduction

Fire protection and prevention is essential for the safe operation of the PCH.

Aluminium composite panels (ACPs) are installed in the PCH façade. The compliance of ACPs has been a national concern in Australia since the Lacrosse apartment fire in Melbourne, in November 2014.

In April 2016 the Building Commission became aware that there was a compliance issue with the fire doorsets at the PCH.

The Building Commission has therefore audited the ACPs and fire doorsets at the hospital.

7.2. Aluminium composite panels

7.2.1. Background

ACPs are a bonded sandwich panel made up of thin aluminium sheet outer layers with a non-aluminium core.

The Building Commission included the ACPs at PCH in this audit to ensure that the PCH façade complies with the NCC, because of the potential risk and the high level of public interest in the Building Commission's 2015 audit of ACPs.

7.2.1.1. Lacrosse apartment fire

The compliance and conformity of ACPs across Australia was highlighted by a façade fire at the Lacrosse building, Latrobe Street, Melbourne on 25 November 2014, which was exacerbated by combustible ACP external wall cladding. This fire prompted the Building Commission's audit of ACPs in Perth high-rise apartment buildings in 2015.

Non-compliance and combustibility of ACPs is a problem recognised around the world. ACPs have been found to exacerbate façade fires in large multi storey buildings, including fires in Azerbaijan (16 storeys), China (28 storeys), four fires in United Arab Emirates (40, 63, 75 and 79 storeys) and the United States (32 storeys). These fires focused international attention on ACPs and their potential to cause or exacerbate building fires.

The cause of the Lacrosse Fire was an unextinguished cigarette on a sixth-floor balcony, which set fire to a plastic container, a timber table top and a nearby air-conditioning unit. According to the Melbourne Metropolitan Fire Brigade (MFB), flames ignited the ACP façade and, aided by the combustible core of the ACP, quickly spread to the top of the building.

MFB identified it was the non-compliant use of the building's external cladding material (ACPs) that mostly contributed to the spread of fire. For further information on compliance of ACPs see section 10 and Appendix B.

The Lacrosse fire prompted the Victorian Building Authority (VBA) to audit 170 high rise residential and public buildings in central Melbourne and surrounds to assess the compliance of ACPs. This audit found a non-compliance rate of 51 per cent.

The high level of non-compliance has led to building regulators reviewing the relevant provisions in the NCC and to prepare amendments to clarify the requirements.

7.2.1.2. *PCH façade*

ACPs are a component of the PCH façade system supplied by Yuanda.

ACPs are used in a number of locations, including as soffit linings, external walls, parapet linings, and sunshades to the external walls of the Intensive Patient Unit (IPU).

John Holland and Strategic Projects engaged experts to ensure façade compliance at PCH:

- Philip Chun was engaged by John Holland as the NCC consultant. Philip Chun's role was to assess the proposed building against NCC 2011, and at the end of the project issue a statement of NCC compliance.
- JMG was engaged by Cameron Chisholm Nicol Architects (CCN) as part of a peer review group for Strategic Projects. JMG's role was to provide technical advice on NCC compliance when required.
- Aurecon was engaged by John Holland as consulting engineers for many aspects of the PCH including the façade design.
- ARUP was engaged by Strategic Projects as a façade engineer advisor. ARUP's role was to provide expert advice and to carry out product selection and verification.

7.2.2. Standards

The contract between John Holland and Philip Chun nominated the NCC 2011 as the applicable building standard for the PCH. This was the most up-to-date edition of the NCC available at the time.

NCC performance requirement CP3 requires that the PCH must be protected from the spread of fire and smoke to allow sufficient time for the orderly evacuation of the building in an emergency.

NCC deemed-to-satisfy solutions for the external façade require the wall to be non-combustible. A non-combustible external wall inhibits fire spread up the exterior of the building.

Combustible attachments are permitted to external walls in some circumstances subject to other NCC provisions.

Philip Chun advised that the external façade complied with the deemed-to-satisfy provisions. The PCH project specification references required standards for ACPs. Aurecon's façade performance specification for PCH included comprehensive technical requirements for the supply and manufacture of the ACPs. This included:

- *Acceptable brand names are Alpolic, Alucobond or equivalent aluminium faced sandwich panel with fire rated core.*
- *Suitable projects where product has been used in Australia to be submitted demonstrating an acceptable track record is required.*

Product manufacturers may obtain certification under the CodeMark certification scheme to demonstrate that a building product complies with the NCC. CodeMark is a voluntary building product certification scheme administered by the Australian Building Codes Board (ABCB). CodeMark issues of a Certificate of Conformity to provide confidence and certainty to regulatory authorities and the building industry.

The high level of non-compliant use of ACPs found in the VBA audit indicates that there may have been significant variation in building surveyors' interpretation of the NCC requirements circa 2011. This may have influenced the design of the PCH. The Building Commission sought evidence to demonstrate that the external façade did meet the deemed-to-satisfy requirements.

7.2.3. Findings

Three types of ACP are installed on the PCH: Alpolic/fr, Alucobond Plus and Haidabond.

7.2.3.1. Alpolic/fr

Alpolic/fr ACPs were manufactured by Mitsubishi Plastics Inc. and supplied by Yuanda (Australia). Alpolic/fr has a CodeMark certificate that states that Alpolic/fr panels meet the NCC requirements CP2 and CP4 to avoid the spread of fire and to maintain tenable conditions in a building and between buildings. Alpolic/fr panel cores contain 80 per cent non-combustible material.

Alpolic/fr panels are installed as external ceiling linings in various areas of the PCH (see Photograph 9). The NCC has different fire resistance requirements for ceilings than for cladding on external walls.

The Building Commission was not provided with evidence that Alpolic/fr panels had been tested to Australian Standard AS1530.1 required to demonstrate whether it is or is not combustible. The CodeMark certificate of compliance with performance requirements CP2 and CP4 is evidence that the Alpolic/fr panels do not constitute an undue risk of fire spread. As a result the Building Commission is satisfied that the use of Alpolic/fr meets the deemed-to-satisfy requirements.

Photograph 9: Alpolic/fr fire resistant panels to external ceiling

Photograph 10: Alucobond Plus panels under the link bridge

7.2.3.2. Alucobond Plus

Alucobond Plus is manufactured by Alucobond Architectural, and supplied by Elcord Pty Ltd. It has a CodeMark certificate that states that Alucobond Plus panels meet the NCC requirements CP2 and CP4 to avoid the spread of fire and to maintain tenable conditions in a building without a sprinkler system. Alucobond Plus panel cores contain 70 per cent non-combustible material.

Alucobond Plus panels are used to line the underside of the hospital's G Block Bridge, which links the PCH to the existing hospital complex, and on a small portion to the external wall where the bridge meets the PCH façade (see Photograph 10).

The Building Commission was not provided with evidence that Alucobond Plus panels had been tested to Australian Standard AS1530.1 required to demonstrate whether it is or is not combustible. The CodeMark certificate of compliance with performance requirements CP2 and CP4 is evidence that the Alucobond Plus panels do not constitute an undue risk of fire spread. As a result the Building Commission is satisfied with Philip Chun advice that the use of Alucobond Plus is compliant with performance requirement CP2 and BCA 2011.

7.2.3.3. Haidabond

Haidabond is manufactured by Jiangyin Litai Ornamental Materials Co., Ltd and supplied by Yuanda (Australia). Haidabond does not have a CodeMark certificate.

Haidabond panels are installed at PCH as sunshades to the Intensive Patient Unit and to the internal side of the wall parapets, located above the roofline (see Photograph 11).

To meet the deemed-to-satisfy provisions, the Haidabond panels must be considered either to be non-combustible as part of the external wall or a combustible attachment to a wall where the attachment does not constitute an undue risk of fire spread via the façade of the building.

The Building Commission was not provided with evidence that Haidabond panels had been tested for combustibility to the Australian Standard AS1530.1 required to demonstrate it formed part of a non-combustible wall. The Building Commission was also not provided with evidence that the Haidabond panels do not constitute an undue risk of fire spread. As a result the Building Commission **was not satisfied**, without further evidence, that the use of Haidabond panels met the deemed-to-satisfy requirements.

Building Commission sought further specialised advice on whether the Haidabond panels present a risk to occupants of the PCH.

Photograph 11: Haidabond panels used as sunshades at PCH

The Building Commission engaged RED Fire Engineers who engaged the CSIRO Infrastructure Technologies testing laboratory in Melbourne to test Haidabond samples provided by Yuanda (Australia). CSIRO tested the panels' mineral content to establish the properties of the product. The CSIRO report concluded that the Haidabond core contained 60 per cent non-combustible mineral fibre.

RED Fire Engineers then evaluated the performance of Haidabond panels installed at PCH under three different fire scenarios:

- internal fire with sprinkler operation;
- internal fire without sprinkler operation; and
- external car fire.

RED Fire Engineers considered that the Haidabond panels installed at PCH do meet the NCC performance requirements to maintain structural stability during a fire and avoid the spread of fire in a sprinklered building.

RED Fire Engineers did not comment on compliance with CP3 where a hospital building must be protected from the spread of fire and smoke to allow sufficient time for the orderly evacuation of the building in an emergency. However, RED Fire Engineers noted that the hospital must have management-in-use procedures when sprinklers are disconnected on a lower level sufficient to deal with the evacuation of the smoke zone on the level above. The

Department of Health has confirmed the North Metropolitan Health Service and Child and Adolescent Health Service will implement the necessary measures in facilities management and emergency procedures.

7.2.4. Rectification

The spread of fire and smoke provisions of CP3 are addressed in the fire engineering report prepared for PCH by NDY.

The Building Commission has provided John Holland, Philip Chun, Strategic Projects and the Department of Health with a copy of RED Fire Engineers' report.

Wood and Grieve and JMG have advised Strategic Projects that an appropriate management-in-use solution when sprinklers are isolated is to contain a fire and prevent a potential breakout through the double glazed curtain wall system.

7.2.5. Conclusion

7.2.5.1. Compliance of ACPs

The Building Commission is satisfied that the use of Alpolic/fr and Alucobond Plus meets the relevant provisions of the NCC for fire resistance. There is also sufficient evidence that these panels meet the performance requirement of the NCC to avoid the spread of fire in a building and between buildings.

The Building Commission is not satisfied the Haidabond panels meet the deemed-to-satisfy provisions of the NCC for fire resistance. Based on RED Fire Engineers' investigation, the Building Commission is satisfied that the Haidabond panels installed at PCH meet the NCC performance requirements to avoid the spread of fire for a sprinklered building. This is to be in conjunction with the management-in-use procedures recommended by Wood and Grieves and JMG for times when the sprinklers are isolated.

7.2.5.2. Evidence of NCC suitability

The lack of compliance documentation for Haidabond panels, including combustibility test reports, highlights the problem with using products that do not have appropriate testing records and certifications.

Consultants and contractors must ensure that all products have appropriate compliance documentation, including combustibility test reports, where NCC deemed-to-satisfy provisions for fire resistance are used. This is required under NCC Vol 1 Part A2.2 *Evidence of suitability*. Where insufficient certification is available, an appropriately qualified fire engineer will need to do a performance assessment to ensure the building meets NCC performance requirements.

7.3. Fire doorsets

7.3.1. Background

One of the principles of fire separation is to divide large buildings into compartments (fire compartments) to improve occupant safety by controlling the spread of fire between compartments.

The NCC and referenced Australian Standards have specific technical requirements for fire-rated walls that separate a building into compartments. Doors in these walls are known as 'fire doors'. The door, door frame, fixings and hinges are collectively known as a 'fire doorset'.

A failure in a fire doorset poses a significant risk to occupants.

7.3.2. Standards

The objective of the NCC requirements for fire resistance is to:

- safeguard people from illness or injury due to a fire in a building;
- safeguard occupants from illness or injury while evacuating a building during a fire;
- facilitate the activities of emergency services personnel;
- avoid the spread of fire between buildings; and
- protect other property from physical damage caused by structural failure of a building as a result of fire.

One way for fire doorsets to meet these requirements is to comply with the relevant deemed-to-satisfy provisions. These provisions reference Australian Standard 1905.1. This standard allows specific variations to the tested doorsets, but variations must be assessed by a Registered Testing Authority.

The fire resistance requirements of building elements, including fire doorsets, are expressed by a Fire Resistance Level (FRL). An FRL has three components:

- Structural adequacy – the ability maintain stability and loadbearing capacity.
- Integrity – the ability to resist the passage of flames and hot gases.
- Insulation – the ability to maintain a non-life-threatening temperature on surfaces not exposed to fire.

The architectural specification for PCH included comprehensive technical requirements for the supply and manufacture of the fire doorsets, including relevant Australian Standards.

7.3.3. Findings

The PCH contains 937 fire doorsets (see Photograph 12). To comply with the deemed-to-satisfy provisions the fire doorsets must comply with the relevant Australian Standards and must meet FRLs specified in the NCC to resist the spread of fire through the hospital.

The fire doorsets were manufactured and supplied by Leaderflush, a UK-based company. A review of John Holland's Materials Finalisation Report for interior doors demonstrated that before selecting Leaderflush to supply the fire doorsets, John Holland considered numerous product and materials criteria including:

- durability;
- appearance;
- adequacy to withstand climatic conditions, including a moderately salt-exposed environment;
- local availability;
- ecologically sustainable design issues;
- flexibility and adaptability;
- whether local trades have the requisite skills to carry out the installation, maintenance and replacement work;
- recommended maintenance regime;
- whole-of-life cost assessment; and
- construction and maintenance occupational health and safety risks.

Despite this evident care in selecting the door supplier, documentation reviewed by the audit team showed that there were on-going issues with the compliance of the fire doorsets from late 2015 and throughout 2016.

In December 2015 John Holland advised Strategic Projects that all fire doorsets required replacement shims and additional fixings. A shim is a thin taper or wedge used to fill small gaps between objects.

In February 2016 Strategic Projects observed unacceptable gaps under the doors and around the frames in the basement.

In late March 2016 John Holland became aware that all fire and smoke doorsets within the PCH did not meet Australian Standard and NCC requirements. Instances of non-compliance included:

- spacing and locations of door frame fixings;
- door leaf gaps;
- timber edge strips fitted to the door leaf;
- hinge positions;
- omission of mortar boxes at specific hardware locations; and
- use of plastic packers in lieu of metal.

John Holland met with the CSIRO regarding the compliance of the fire doorsets. The CSIRO advised that Australian Standard AS1905.1 permitted variations, subject to certification of compliance by a Registered Testing Authority such as CSIRO. CSIRO concluded that the fire doorsets would be able to achieve the required FRL subject to 10 detailed technical recommendations.

Photograph 12: Fire rated doorset

7.3.4. Rectification

Weekly reports from Strategic Projects provide regular updates on how the non-compliant doorsets were rectified. From October 2015 Strategic Projects noted concerns raised by JMG about the certification of fire doorsets and the quality and compatibility of doors and door frames.

Leaderflush went into receivership in December 2015 before they finished manufacturing the full consignment of fire doorsets. The Building Commission was not able to find evidence of John Holland investigating the financial stability of Leaderflush prior to their engagement; however Leaderflush was an established door manufacturer and global supplier.

John Holland subsequently engaged Arrow Fire Services, an Australian fire separation specialist, to supply the balance of the fire doorsets.

At this time John Holland did an audit of all the PCH doors, including fire doorsets. The audit identified 1,780 door-related issues. John Holland tasked a team of 20 staff to review and repair the doors. John Holland and Strategic Projects agreed that John Holland would rectify at least 30 doors per day. John Holland sub-contracted Fire Technologies Australia to modify and reinstall the doors and frames in accordance with CSIRO's recommendations. Each non-compliant fire doorset was removed, remediated as required and reinstalled.

Arrow Fire Services inspected the reinstalled doors. They also carried out the overall certification and final tagging of the fire doorsets, as required by AS 1905.1.

During the reinstallation of the fire doorsets, Strategic Projects also undertook a number of inspections.

The certification and tagging of the fire doorsets was completed by late August 2016. In September 2016 the fire door certification was delivered to Strategic Projects.

In October 2016 Strategic Projects engaged JMG to randomly audit fire and smoke doorsets across the PCH site and review the certifications and documentation.

In November 2016 JMG advised Strategic Projects that their audit only identified minor issues. JMG and Arrow Fire Services met to discuss the resolution of these minor matters.

In January 2017 Strategic Projects advised that all fire doorsets are now compliant.

7.3.5. Conclusion

The Building Commission is satisfied that John Holland acted appropriately to rectify the fire doorsets.

The documentation for the rectification of the fire doorsets, including testing and assessment by external parties, demonstrates that the PCH fire doorsets now meet all requirements of the NCC and Australian Standards.

8. Other issues

8.1. Introduction

This audit assessed the compliance of the VE panels and glazing within the PCH curtain wall façade.

The Building Commission audited the VE panels because during transit between China and Australia 1,641 VE panels were damaged. The audit examined why the damage occurred, the extent of the damage, the remediation plan, and whether John Holland was taking appropriate action.

The Building Commission audited the glazing because there have been a number of recent reports of non-compliant glazing assemblies in buildings in Australia generally (not specific to Yuanda (Australia) or PCH).

The extent of non-compliant glazing assemblies has been highlighted by Tracey Gramlick of the Australian Windows Association who has stated:

> *"Non-compliant products have reached tipping point. It's flooding in at the moment,".*[6]

The audit assesses whether John Holland has taken appropriate measures to ensure the PCH façade is compliant.

8.2. Background

A curtain wall is defined as a:

> *'Thin, usually aluminum-framed wall, containing in-fills of glass, metal panels, or thin stone. The framing is attached to the building structure and does not carry the floor or roof loads of the building. The wind and gravity loads of the curtain wall are transferred to the building structure, typically at the floor line'.*[7]

The VE panels and glazing within the curtain wall at PCH were both supplied by Yuanda (Australia).

8.2.1. Vitreous enamel panels

The VE panels used on the hospital are a bonded sandwich panel made up of vitreous enamel-coated decarburised steel outer layers with an aluminium honeycomb internal core (see Photograph 13).

VE panels are used throughout the hospital exterior and several internal locations, including:

- as part of the external curtain wall cladding system; and
- as an architectural feature at an entry and decorating of some columns .

Over 6,000 VE panels are installed in the external façade of the PCH. They include a range of colours: white, black, light green and dark green.

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[6] *http://www.abc.net.au/news/2015-06-24/imported-construction-materials-put-lives-at-risk:-specialists/6571398;* http://www.absolutebalustrades.com.au/News/Defects-in-Chinese-glass

[7] The Whole Building Design Guide – National Institute of Building Sciences http://www.wbdg.org/systems-specifications/building-envelope-design-guide/fenestration-systems/curtain-walls

Photograph 13: White vitreous enamel panels at Perth Children's Hospital

8.2.2. Curtain wall glazing

The curtain wall system used on the hospital includes several different glazed assemblies. These assemblies include various double glazed and laminated glazed units, with heat strengthened, laminated, and/or toughened glass. Many have low emissivity (Low-E) coatings to reduce solar heat gain inside the building.

8.3. Standards

8.3.1. Vitreous enamel panels

NCC provisions were not considered during the audit of the VE panels as the panels were not considered to pose a fire risk. This part of the audit is assessing damage incurred during transport. This is not NCC compliance related, but instead specification compliance and condition related and speaks to performance of the parties involved.

Aurecon's façade performance specification includes comprehensive technical requirements for the supply and manufacture of the VE panels. These included:

- *Protect the Works to prevent damage and staining during transportation, storage and erection until Practical Completion.*
- *The Subcontractor is to submit protective measures for review prior to transportation and installation.*

8.3.2. Curtain wall glazing

Aurecon's façade performance specification includes comprehensive technical requirements, including compliance with relevant Australian Standards, for the supply and manufacture of the glazing.

The contract between John Holland and Philip Chun nominated the then-current edition of the NCC (2011) as the applicable building standard for the PCH.

Curtain wall systems are required to meet the applicable NCC performance requirements for glazing and curtain walls.

8.4. Vitreous enamel panels

8.4.1. Findings

8.4.1.1. Procurement of the VE panels

The contract to supply the VE panels was awarded to Yuanda (Australia). Yuanda (Australia) via their head company Yuanda (China) contracted Zhejiang Kaier New Materials Co., Ltd to supply the VE panels. The company is based in the Zhejiang region of China and supplies VE panels globally. Its website claims the company has 70 per cent market share in China. The panels installed at PCH were imported to Australia from China.

Yuanda (Australia) produced a Project Quality Plan that included the supply and installation of the VE panels.

The performance and composition of individual materials was verified during review at the sample submission stage.

John Holland ensured the VE panels were tested for their acoustic, air permeability, seismic, water and structural properties. Testing was undertaken both off-site and on-site.

8.4.1.2. Damaged VE panels

John Holland provided information to show that some VE panels were damaged in transit between China and Australia. This damage was primarily chips, dents and detachment of enamel coating from the steel base sheet, which compromises the panel's durability. According to information from John Holland the damage was reported to have affected 1,641 panels out of a shipment of over 6,000 panels.

Yuanda (Australia) acknowledged that some panels were damaged in transit, but also claims that some damage to panels occurred on site, including after installation.

According to Yuanda (Australia), in the course of more than 20 visits to the Chinese factory, John Holland made no comment to suggest that the final packing solution of the panels was not satisfactory.

Yuanda (Australia) repaired a sample of the damaged panels to test the effectiveness of the repair process against the specification. The damage and initial repair attempts by Yuanda (Australia) were inspected and investigated by various parties, including ARUP. Yuanda (Australia) proceeded to repair the damaged panels.

Due to the nature of a vitreous enamel coating on steel John Holland and Strategic Projects determined that the repairs to the panels were not adequate and that therefore the only option was to replace them.

In December 2015 John Holland requested that Yuanda (Australia) replace the damaged panels. Yuanda (Australia) maintained the damaged panels could be adequately repaired. This has led to a contractual dispute between John Holland and Yuanda (Australia).

8.4.1.3. Why the panels were installed

Because of the contractual dispute with Yuanda (Australia), John Holland decided to procure replacement panels from alternative suppliers. This solution had a long lead time as the only suitable supplier was overseas.

In order to keep to the construction timeframe, John Holland decided to install the panels which Yuanda (Australia) was repairing with the intention of replacing them at a later date. John Holland and Strategic Projects determined that the temporary installation of panels had no adverse impact on the proper functioning of the hospital.

The panels were installed to provide a temporary finished product, while the replacement panels were being manufactured.

8.4.2. Rectification

8.4.2.1. Replacement of VE panels

John Holland's documentation demonstrates tighter controls in place for the transportation of the new panels to prevent similar damage from occurring.

In April 2016 John Holland decided that the replacement panels should be sourced from a different manufacturer and engaged Omeras GmbH, a German-based manufacturer, to supply the replacement panels.

In November 2016 ARUP, the façade engineer engaged by Strategic Projects, inspected Omeras' factory in Germany. ARUP reported that there were no concerns with the manufacturing process and quality assurance procedures of Omeras.

Initially eight panels were received onsite. Strategic Projects undertook a quality inspection and noted only minor issues.

In December 2016, following further reviews on the quality of the panels, Strategic Projects commenced joint inspections of the new VE panels procured from Omeras. Generally the quality was found to be of a high standard with very minimal issues.

In December 2016 replacement panel installation was commenced by GCS on South Block. Replacement of the damaged panels is expected to continue into 2017.

As of February 2017 John Holland was yet to provide Strategic Projects with a methodology and program to complete the replacement works after practical completion is achieved.

8.4.3. Conclusion

The Building Commission is not in a position to determine whether the damage to the panels supplied by Yuanda (Australia) could be satisfactorily repaired.

Once John Holland had determined to replace the damaged panels, its decision to fit the damaged panels on a temporary basis to reduce delays was appropriate.

8.5. Curtain wall glazing

8.5.1. Findings

Yuanda (Australia) supplied the curtain wall system components for PCH and was given thorough design specifications. A team of consultants developed these specifications, including:

- Aurecon (engineer);
- ARUP (façade engineer);
- Philip Chun (building surveyor); and
- Woods Bagot Pty Ltd (architect).

The specifications for the glass curtain wall system met the technical requirements of the NCC and Australian Standards.

John Holland contracted Yuanda (Australia) to manufacture, import and install the curtain wall system. Yuanda (Australia) subcontracted Yuanda (China) to manufacture and ship the components, Worldwide Logistics to manage customs clearance, local transport and storage and GCS Facades Pty Ltd to install the glazing at PCH.

Yuanda (China) used a range of Chinese suppliers to assemble and manufacture the curtain walling system and unitised atrium roof glazing panels. These were:

- Tianjin CSG Architectural Glass Co., Ltd (CSG Tianjin);
- Shanghai Yaohua Pilkington Glass Group Co., Ltd (SYP);
- Beijing North Glass Safety Glass Co., Ltd (North Glass); and
- Gugangdong Avic Special Glass Technology Co., Ltd (SanXin).

John Holland collected numerous samples and test data to document the glazing components complied with relevant standards and NCC requirements. During the Building Commission's audit of this documentation, John Holland provided quality assurance and quality control documentation including:

- Yuanda (Australia) Project Quality Plan;
- Yuanda (Australia) Off-site QA and QC Procedure;
- Tianjin CSG Architectural Glass Quality Plan;
- SYP Processing Glass Quality Plan / Quality Control Procedure;
- North Glass Safety Glass Quality Control Procedure; and
- SanXin Quality Control Plan.

Yuanda (Australia) provided a certificate of compliance for the curtain walling system and a façade installation certificate. These certificates verified compliance with the NCC and Australian Standards.

8.5.2. Rectification

No compliance issues were identified that required remediation.

8.5.3. Conclusion

The Building Commission considers that the glazing meets the relevant requirements of the NCC 2011.

Photograph 14: Curtain wall glazing at Perth Children's Hospital

9. Recommendations

The Building Commission audit has highlighted the Australia-wide building industry issue of material and product non-compliance and non-conformance.

The audit has also found that there is a need for further information about water supply, water chemistry and its interaction with plumbing fixtures and fittings to determine whether the plumbing issues at the PCH are an isolated event or evidence of a broader issues that may require regulation and building practice changes.

In light of the findings of the audit, the Building Commission recommends the following:

9.1. Recommendation 1 – non-conforming products and materials

- The Building Commission recommends that the Building Minister's Forum concludes its current work on the issue of non-compliant and non-conforming building materials and products and the establishment of a national regulators forum to coordinate education and compliance activities.
- The Building Commission recommends that building contractors implement more thorough quality assurance and quality checking procedures when sourcing materials and components.

The outcome will be an increase in efficiencies for the building industry, including individual companies. This will be done by reducing the amount of time and resources spent on rectifying non-compliant or non-conforming building elements.

9.2. Recommendation 2 – lead in plumbing networks

9.2.1. Perth Children's Hospital

- The Building Commission recommends that the State appoints an independent organisation to review the existing test results and carry out whatever additional tests are needed to determine the proportions of lead that came from the identified sources of lead at the PCH.

9.2.2. Other new buildings

- The Building Commission recommends that the Building Ministers Forum requests the ABCB to collate existing test results and commission whatever new testing is required to determine whether lead leaching from brass plumbing fittings is contributing to lead levels above the ADWG in Australian buildings.

This is to determine whether the elevated lead content found at the PCH is an isolated incident or a symptom of a wider issue.

10. References and further information

10.1.1. Referenced Acts and Regulations:

Government of Western Australia, *Building Act 2011*

Government of Western Australia, Building Regulations 2012

Government of Western Australia, *Builders' Registration Act 1939*

Government of Western Australia, *Building Services (Complaint Resolution and Administration) Act 2011*

Government of Western Australia, *Building Services (Registration) Act 2011*

These documents can be downloaded from the State Law Publisher website at www.slp.wa.gov.au.

10.1.2. Further information

10.1.2.1. Asbestos

Further information to reduce the risk of importing ACM is available from the Asbestos Safety and Eradication Agency at www.asbestossafety.gov.au.

Information on asbestos health risks is available from Enhealth in its guide Asbestos: A Guide for Householders and the General Public, available at www.health.gov.au/internet/main/publishing.nsf/Content/ohp-enhealth-asbestos-may2012.htm.

An *Asbestos Importation Review Report* is available from the Department of Immigration and Border Protection, at www.border.gov.au/ReportsandPublications/Documents/reviews-and-inquiries/asbestos-importation-review.pdf.

10.1.2.2. Lead

Harvey, Handley and Taylor, 2016, Widespread copper and lead contamination of household drinking water, New South Wales, Australia, *Environmental Research* vol 151, pp. 275-285. www.sciencedirect.com/science/article/pii/S0013935116303280

10.1.2.3. Aluminium composite panels

Metropolitan Fire Brigade issued its Post Incident Analysis Report in April 2015, available online at www.mfb.vic.gov.au/Media/docs/Post_Incident_Analysis_for_Lacrosse_Docklands_-_25_11_2014%20-%20FINAL-dd61c4b2-61f6-42ed-9411-803cc23e6acc-0.PDF

Victorian Building Authority (VBA) External Wall Cladding Audit Report was released on 17 February 2016. The report is available online at www.vba.vic.gov.au/__data/assets/pdf_file/0016/39103/VBA-External-Wall-Cladding-Report.pdf

VBA issued an Industry Alert on 24 February 2016, available online at www.vba.vic.gov.au/__data/assets/pdf_file/0010/39349/Industry-Alert-External-walls-and-BCA-compliance.pdf

CSIRO issued 'Fire safety guideline for external walls' on 18 April 2016, available online at www.csiro.au/~/media/Do-Business/Files/Services/CSIRO-External-Wall-Safety-Guide-18-04-2016-PDF.pdf?la=en&hash=61CA5DDDB4145D2F1C8E8147607272EDCC08F70F

The Building Commission issued Industry Bulletin 54 'External wall cladding – fire safety' on 28 May 2015, available online at www.commerce.wa.gov.au/sites/default/files/atoms/files/ib_054_2015.pdf

The Building Commission issued Industry Bulletin 62 'Victorian Building Authority external wall cladding audit report' in March 2016, available online at www.commerce.wa.gov.au/sites/default/files/atoms/files/ib_062_vba_wall_cladding_0.pdf

The Building Commission issued an Interim Report ‘Aluminium composite panelling in high-rise buildings’ on 11 April 2016, available online at www.commerce.wa.gov.au/sites/default/files/atoms/files/acp_interim_report_final.pdf

At its meeting on 19 February 2016, the Building Ministers’ Forum agreed to develop and implement a range of measures to address risks associated with high risk cladding products on high rise buildings. The ABCB issued the Advisory Note 2016-3 ‘Fire Performance of External Walls and Cladding’ in August 2016, available online at www.abcb.gov.au/-/media/Files/Resources/Education-Training/Advisory-Note-2016-3-Fire-performance-of-external-walls-cladding.pdf

VBA Media Release 17 February 2016, available online at www.vba.vic.gov.au/a-z-information/audit-of-cladding-on-high-rise-buildings

11. Appendix A – National Construction Code 2011

A1.1 Definitions

Loadbearing means intended to resist vertical forces additional to those due to its own weight.

Combustible means—

(a) Applied to a material — combustible as determined by AS 1530.1.

(b) Applied to construction or part of a building — constructed wholly or in part of combustible materials.

Non-combustible means—

(a) Applied to a material — not deemed combustible as determined by AS 1530.1 — Combustibility Tests for Materials.

(b) Applied to construction or part of a building — constructed wholly of materials that are not deemed combustible.

C1.10 Fire Hazard Properties

a) The fire hazard properties of the following linings, materials and assemblies in a Class 2 to 9 building must comply with Specification C1.10:
    i. Floor linings and floor coverings.
    ii. Wall linings and ceiling linings.
    iii. Air-handling ductwork.
    iv. Lift cars.
    v. In Class 9b buildings used as a theatre, public hall or the like—
        A. fixed seating in the audience area or auditorium; and
        B. a proscenium curtain required by Specification H1.3.
    vi. Escalators, moving walkways and non-required non fire-isolated stairways or pedestrian ramps subject to Specification D1.12.
    vii. Sarking-type materials.
    viii. Attachments to floors, ceilings, internal walls and the internal linings of external walls.
    ix. Other materials including insulation materials other than sarking-type materials.

b) Paint or fire-retardant coatings must not be used to make a substrate comply with the required fire hazard properties.

c) The requirements of (a) do not apply to a material or assembly if it is—
    i. plaster, cement render, concrete, terrazzo, ceramic tile or the like; or
    ii. a fire-protective covering; or
    iii. a timber-framed window; or
    iv. a solid timber handrail or skirting; or
    v. a timber-faced solid-core door or timber-faced fire door; or
    vi. an electrical switch, socket-outlet, cover plate or the like; or
    vii. a material used for—
        A. a roof insulating material applied in continuous contact with a substrate; or
        B. an adhesive; or
        C. a damp-proof course, flashing, caulking, sealing, ground moisture barrier, or the like; or
    viii. a paint, varnish, lacquer or similar finish, other than nitro-cellulose lacquer; or
    ix. a clear or translucent roof light of glass fibre reinforced polyester if—
        A. the roof in which it is installed forms part of a single storey building required to be Type C construction; and
        B. the material is used as part of the roof covering; and
        C. it is not closer than 1.5 m from another roof light of the same type; and

D. each roof light is not more than 14 m^2 in area; and
E. the area of the roof lights per 70 m^2 of roof surface is not more than 14 m^2; or

x. a face plate or neck adaptor of supply and return air outlets of an air handling system; or
xi. a face plate or diffuser plate of light fitting and emergency exit signs and associated electrical wiring and electrical components; or
xii. a joinery unit, cupboard, shelving, or the like; or
xiii. an attached non-building fixture and fitting such as—
    A. a curtain, blind, or similar decor, other than a proscenium curtain required by Specification H1.3; and
    B. a whiteboard, window treatment or the like; or
xiv. any other material that does not significantly increase the hazards of fire.

C1.12 Non-combustible materials

The following materials, though combustible or containing combustible fibres, may be used wherever a non-combustible material is required:

a) Plasterboard.
b) Perforated gypsum lath with a normal paper finish.
c) Fibrous-plaster sheet.
d) Fibre-reinforced cement sheeting.
e) Pre-finished metal sheeting having a combustible surface finish not exceeding 1 mm thickness and where the Spread-of-Flame Index of the product is not greater than 0.
f) Bonded laminated materials where—
    i. each laminate is non-combustible; and
    ii. each adhesive layer does not exceed 1 mm in thickness; and
    iii. the total thickness of the adhesive layers does not exceed 2 mm; and
    iv. the Spread-of-Flame Index and the Smoke-Developed Index of the laminated material as a whole does not exceed 0 and 3 respectively.

Specification C1.1

2.4 Attachments not to impair fire-resistance

a) A combustible material may be used as a finish or lining to a wall or roof, or in a sign, sunscreen or blind, awning, or other attachment to a building element which has the required FRL (fire resistance level) if—
    i. the material is exempted under C1.10 or complies with the fire hazard properties prescribed in Specification C1.10; and
    ii. it is not located near or directly above a required exit so as to make the exit unusable in a fire; and
    iii. it does not otherwise constitute an undue risk of fire spread via the facade of the building.
b) The attachment of a facing or finish, or the installation of ducting or any other service, to a part of a building required to have an FRL must not impair the required FRL of that part.

3. TYPE A FIRE-RESISTING CONSTRUCTION

3.1 Fire-resistance of building elements

In a building required to be of Type A construction—

a) each building element listed in Table 3 and any beam or column incorporated in it, must have an FRL not less than that listed in the Table for the particular Class of building concerned; and
b) external walls, common walls and the flooring and floor framing of lift pits must be non-combustible; and
c) any internal wall required to have an FRL with respect to integrity and insulation must extend to—
   i. the underside of the floor next above; or
   ii. the underside of a roof complying with Table 3; or
   iii. if under Clause 3.5 the roof is not required to comply with Table 3, the underside of the non-combustible roof covering and, except for roof battens with dimensions of 75 mm x 50 mm or less or sarking-type material, must not be crossed by timber or other combustible building elements; or
   iv. a ceiling that is immediately below the roof and has a resistance to the incipient spread of fire to the roof space between the ceiling and the roof of not less than 60 minutes; and
d) a loadbearing internal wall and a loadbearing fire wall (including those that are part of a loadbearing shaft) must be of concrete or masonry; and
e) a non-loadbearing—
   i. internal wall required to be fire-resisting; and
   ii. lift, ventilating, pipe, garbage, or similar shaft that is not for the discharge of hot products of combustion, must be of non-combustible construction; and
f) the FRLs specified in Table 3 for an external column apply also to those parts of an internal column that face and are within 1.5 m of a window and are exposed through that window to a fire-source feature.

12. Appendix B – Industry Bulletin 54, May 2015

Government of **Western Australia**
Department of **Commerce**

Building Commission

INDUSTRY BULLETIN

IB 054/2015

External wall cladding – fire safety

Fire safety concerns have been raised on the use of certain aluminium composite panels for external wall cladding where that product had not been tested or demonstrated to meet the requirements of the Building Code of Australia (BCA) for that use. Such products can lead to a rapid vertical spread of a fire via the façade of the building which raises serious safety concerns.

Building legislation in Western Australia requires buildings to comply with the BCA which includes requirements on fire safety. In general the BCA Volume 1 contains provisions for external walls of buildings falling under type A and type B construction (typically medium rise and high rise commercial buildings including residential apartment buildings) to be non-combustible.

Building surveyors, builders, designers and owners must ensure that the fire resistance levels of external walls comply with the requirements of the BCA and any attachments to those walls must also meet the BCA Deemed-to-Satisfy provisions under clause 2.4 of the Specification C1.1, or alternatively are the subject of a performance based building solution that has been approved as meeting the Performance Requirements of the BCA.

It is important to note that while a product may have relevant certification for compliance with certain provisions of the BCA and be suitable to use in certain circumstances, that product may not have been tested or assessed for all relevant building standards. For example, an external wall cladding product may have compliance certification for building standards relating to weatherproofing and/or structural fixing requirements, but may not have been tested for relevant fire resistance requirements. Therefore it may not be suitable to use that product where an external wall is required to meet fire resistant safety requirements.

Building surveyors must be satisfied that products being specified as part of a building proposal comply with applicable building standards before signing a certificate of design compliance. Furthermore building surveyors should be satisfied products used in buildings comply before signing a certificate of construction or building compliance.

Builders are reminded of their obligations to ensure the building is completed in accordance with the plans and specifications specified in the applicable certificate of design compliance in relation to the building permit and the overarching requirement to comply with applicable building standards.

When using a building product you should ensure it is suitable for the specific circumstance and that it complies with all relevant building standards. If you have been involved in the design, certification or installation of aluminium composite external wall panels for a multi-storey building you are advised to check the compliance of the product.

Any non-compliant use of aluminium composite type panels should be reported to the Building Commission and the relevant permit authority in the first instance.

May 2015

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