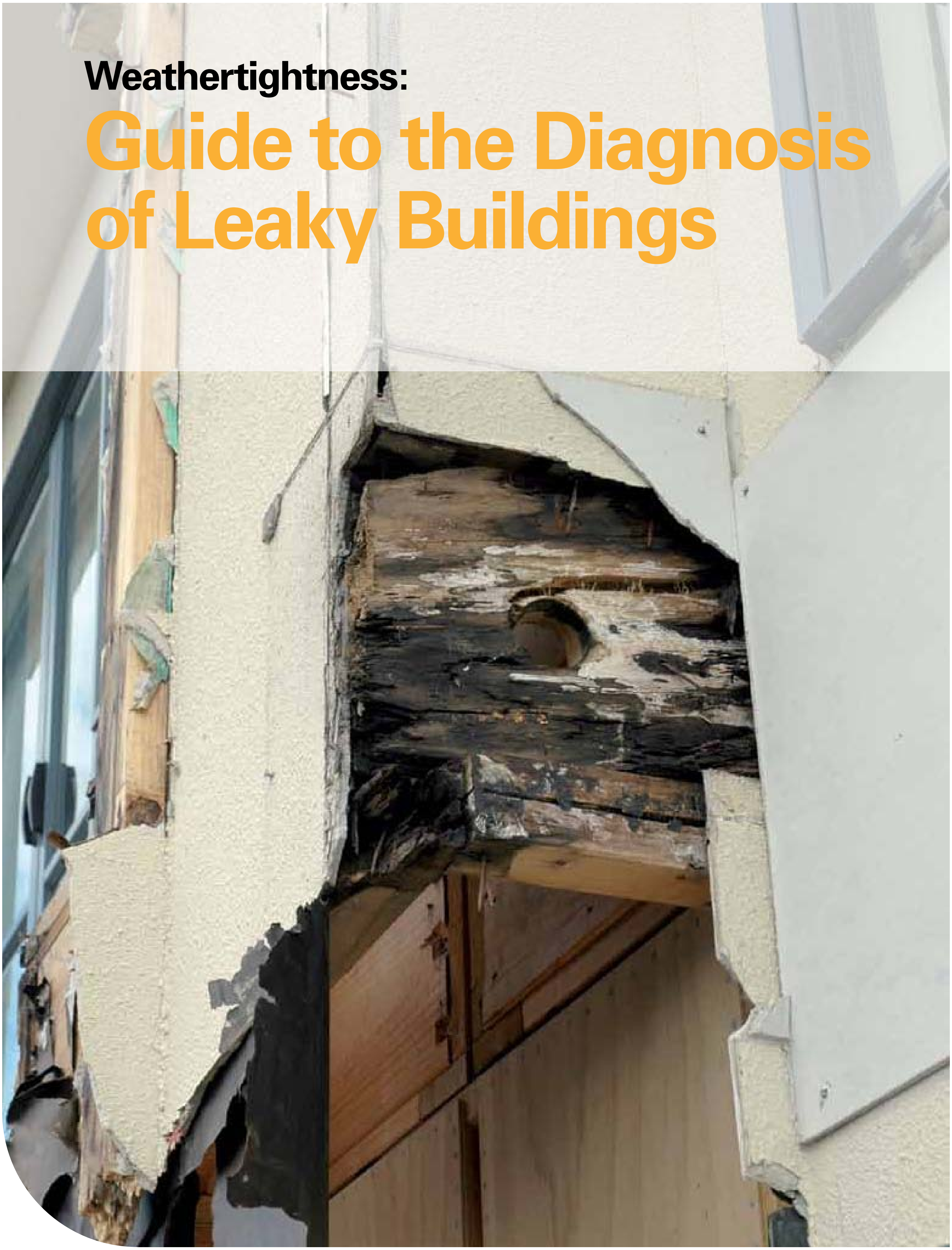
Department of
Building and Housing
Te Tari Kaupapa Whare

Weathertightness:
Guide to the Diagnosis of Leaky Buildings



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PURPOSE

The purpose of this document is to provide guidance on diagnosing weathertightness defects in buildings to:

- help set good practice standards to be followed by those diagnosing weathertightness defects, and
- contribute to the efficient and effective repair of buildings that are leaking.

Accurately diagnosing a leaking building requires a high degree of skill, experience and knowledge – this guidance does not replace the need for those carrying out this work to have undertaken thorough professional development with regular training updates and on-site experience.

This guidance is not confined to the procedures of any particular agency or organisation. Note, however, that when preparing a diagnostic report, the assessor should be aware of the context. If there is a possibility that the report will be used in a claim under the Weathertight Homes Resolution Services Act, for example, or even in court, the assessor should ensure the report will be fit for that purpose.

Because any guidance can only apply generally, anyone using this guidance must take account of the particular circumstances and should not rely on this guide as the sole source of information for assessing leaky buildings.

AUDIENCE

This guidance is intended for those who diagnose weathertightness defects in leaking buildings, for example building assessors or building surveyors (referred to generically as the 'assessor' throughout this guidance). While the information here will not be new to experienced assessors, it describes a benchmark for good practice currently accepted within the sector.

The guidance will also be useful for those training to become assessors and those who use and read diagnostic reports on leaking buildings, such as homeowners (referred to as the 'owner'), remediation designers and building consent officials.

The use of this guide does not relieve the users of their responsibility to comply with the Building Act 2004, the Building Code or any other regulatory obligation.

SCOPE

The process of diagnosing a leaking building is like all diagnostic activities – it aims to balance gathering sufficient information to form the basis of robust conclusions while avoiding excessive cost or undertaking too much destructive examination.

This guidance will help an assessor address the following aspects of the diagnosis of a leaking building.

- Is the building leaking?
- Where does it leak and why?
- What damage has been caused by the leaks?

- Where and why might it leak in the future?
- What damage is likely to be caused in the future?
- What remediation work is recommended?
- What is the estimated cost for the recommended remediation?

This guidance provides technical advice and is in no way intended to provide advice on claims or liability. Any person with concerns or questions about a claim should seek independent legal advice.

The guidance covers fact-finding, and investigation of and producing reports on leaking buildings to provide a clear starting point for the next, separate stage of detailed remediation design.

In this document, a 'leaking building' refers to the penetration of water/moisture (either unintended or greater than intended) that results in damage to the building. While damage may not necessarily compromise the structural integrity of the framing, it can result in physical change to the building materials. Such changes may include the presence of significantly higher moisture levels than would normally be expected in the circumstances, saturated cladding or surface bubbling, and the loss of usefulness of particular materials.

This guidance covers primarily timber-framed buildings that generally fall within the scope of NZS 3604.

A large proportion of the NZS 3604-type buildings that have been assessed during the last decade have been private residences with monolithic cladding systems that were constructed in the early 1990s through to the mid-2000s. Some of the leaks affecting these buildings arise directly from failures of the monolithic cladding system, while the frequent use of untreated, kiln-dried radiata pine framing has exacerbated the damage caused by leaks.

With suitable expertise and experience, the principles of diagnosis in this guidance may also be applied to buildings outside the scope of NZS 3604 or multi-storey apartment buildings that are either timber-framed or contain some timber framing. Refer to Appendix III for more information.

This guidance provides advice on technical areas and practices that are current at the time of publication, however these are continually developing. This document is based on, but does not reproduce, scientific principles and knowledge that are fundamental to the understanding and remediation of leaking buildings, such as weathertightness science or the movement characteristics of water.

THE ASSESSOR

A competent assessor of leaking buildings will need to have appropriate knowledge, skills and experience to carry out accurate investigation and reporting. These include:

- a sound knowledge of the New Zealand Building Act, the New Zealand Building Code, Compliance Documents and relevant Standards, including an understanding of construction methods and systems used in New Zealand, and
- an understanding of water management principles, including the '4Ds' of weathertightness design (Deflection, Drainage, Drying and Durability), and
- experience with on-site diagnosis and writing clear technical reports and, ideally, experience on successful remediation projects.

Assessors need to be able to show ongoing competency and expertise. This might include membership of a professional organisation and undertaking specific training in assessing leaking buildings (such as training offered by the New Zealand Institute of Building Surveyors – NZIBS).

In addition, an assessor may wish to engage a more experienced assessor to review their work, in particular the analysis of defects and assessment of resulting damage and any potential future damage. Checking the recommendations against the basis of the investigation and defect analysis may also be helpful.

ADDITIONAL SPECIALIST EXPERTISE

There are various aspects of a diagnosis where additional specialist expertise is likely to be required, including advice on both weathertightness and non-weathertightness matters.

For weathertightness matters, these may include expertise in mould/fungi, biodeterioration, façade engineering, external joinery manufacture and installation, corrosion or material science. Expertise for non-weathertightness matters may include structural or fire engineering, health and safety, or insulation advice.

In terms of health and safety, the following two aspects are particularly important.

- Hazardous moulds – Assessors often discover moulds which may affect the health of building occupants or those working in the building. It is important to send samples of any moulds to which building occupants or workers may be exposed to a specialist laboratory for identification and/or arrange for air sampling by a specialist organisation to ensure appropriate safety precautions are taken.
- Imminent structural failure – Where the assessor considers there is any likelihood of imminent structural failure of a building or part of a building, a structural engineer should be consulted promptly. The assessor should also alert the building owner of the dangers and may need to notify the relevant territorial authority as well as any occupants.

CONTINUOUS RE-EVALUATION THROUGHOUT THE DIAGNOSIS

Assessors need to continually test their understanding of how water has penetrated the exterior envelope and caused damage. Initial hypotheses often prove to be inaccurate, so repeated re-evaluation is necessary before conclusions can be reached and substantiated.

Weathertightness problems often arise from a combination of issues rather than from the failure of one individual product or detail. Practice also shows that the steps for evidence collection and analysis may not be strictly sequential.

THE DIAGNOSTIC PROCESS

This document sets out the process for a full diagnostic weathertightness investigation. This involves a detailed investigation and report to assess where and why a building is leaking, with an initial repair proposal, and estimated costs to remediate the weathertightness defects and damage. It will also include an assessment of work to prevent potential future damage.

Note that this guidance only provides technical advice on carrying out investigation and reporting, and is in no way intended as advice on claims or liability.

The diagnostic process in this guidance is summarised as a series of steps in Figure 1 below.

Figure 1: The diagnostic process

Step 1: Pre-site work and visual investigation

Receiving owner's briefing, sourcing documents, meeting building occupants, visual building inspection inside and out

Step 2: Non-invasive investigation

Non-invasive investigation to identify potential problem locations that require further investigation

Step 3: Invasive investigation

Invasive tests to determine moisture levels and presence of timber decay

Step 4: Destructive testing

Cut-outs for inspecting construction detailing and framing, with timber sample collection for on-site and laboratory analysis

Step 5: Defect analysis

Evaluating evidence to identify causes and consequences of moisture entry, the extent of the damage and potential for future damage

Step 6: Remediation recommendation

Developing a cost-effective remediation proposal which meets the relevant regulatory requirements, with cost estimates

Step 7: Reporting

Assembling the investigation, evidence and recommendation into a logical and comprehensive report

Step 1 – Pre-site work and visual investigation

Step 1 – Pre-site work and visual investigation

At the commissioning stage for the diagnostic report, it is important to establish a clear brief. This includes understanding the building owner's requirements for the scope and purpose of the investigation, and any limitations they may have (such as timing or financial constraints). The assessor should confirm the extent of the investigation with the building owner, including obtaining their consent for any required destructive testing, cladding removal and sampling. Where there is more than one owner, the assessor should clarify at the outset who has the authority to represent all owners.

The assessor's role is to be an impartial expert and not an advocate for any particular interested party.

1.1 PRE-SITE WORK

The assessor should look for any relevant information about the building's construction. Useful sources include:

- consent documentation and inspection records
- producer statements and warranties
- manufacturers' publications
- the Building Code and relevant Acceptable Solutions at the time of construction
- Standards or codes of practice
- BRANZ publications or library materials
- consultants who may have been involved in previous repairs.

The assessor should read the building consent documentation before inspecting the site and note any significant design/specification items for weathertightness.

The assessor should try to ascertain whether there have been any previous leaking problems and repair attempts and, if so, what work was done and when. Site investigations and discussions with building occupants and owners may provide information about previous leaks and repairs.

1.2 SITE VISITS

Appropriate access and entry approvals should be obtained from the owner and any occupiers (and neighbours, if necessary to gain access) before going on site. Any difficulties accessing parts of the building, such as roof areas, sub-floors or adjacent tenancies, should be noted.

Weather conditions during the previous month, and those at the time of each site visit, should be recorded.

The assessor should identify any potential hazards likely to be encountered during the investigation and take the necessary safety precautions. This includes precautions to protect both themselves and the building occupants when extracting mould and fungi samples. The assessor should look out for any likelihood of imminent structural failure, in which case a structural engineer should be consulted promptly.

The assessor should also alert the building owner to the dangers and may need to notify the relevant territorial authority as well as any occupants.

1.2.1 Building occupant comments

Information gathered from the building occupants and owners can provide useful background information about when leaks were first noticed, where leaks appear, the incidence of leaks in different wind directions and if there are other signs of moisture inside the building.

Past attempts may have been made to fix leaking (such as inserting more sealant). Occupants may be able to provide information about any changes in leak patterns following repair attempts. This can be useful following a prolonged dry period when moisture cannot be readily detected using moisture meters.

However, not all observations of high moisture contents may be weather-related. For example, they may be caused by leaking plumbing pipes or high moisture build-up within internal spaces such as in bathrooms.

The following questions may be useful as a starting point for discussions with building occupants.

- What leaks or water damage are evident?
- When did you first notice the leaks?
- Do leaks vary depending on the wind direction and strength?
- What changes have resulted from any past attempts to fix leaks?
- Who was involved in altering or repairing the building?
- Is there any other relevant information available?

Notes should be kept of conversations with occupants, including who the assessor spoke to and when, as these can be valuable for any later reference.

1.2.2 Visual investigation for evidence of leaks

Damage is usually hidden and may not be obvious during a visual examination. Indications of moisture problems can include:

- sagging ceiling linings
- sagging or uneven floor surfaces
- stained or rotting carpet or rusting of carpet fixings
- lifting of vinyl floors
- swelling of skirtings or other trims
- dark staining on materials or finishes
- bubbles forming under paintwork and other deterioration of paintwork and substrate materials
- mould and mildew growth on surfaces
- musty smells
- efflorescence
- cracks
- corrosion of fixings
- ants, slaters or borer (in some situations)
- water dripping from soffits or behind the bottom of wall claddings long after rain has stopped.

1.2.3 Building design assessment

A general visual assessment should be carried out to gain an overall appreciation of the risk factors relating to the building's design. A number of factors contribute to the risk of water penetration, such as design features, detailing and complexity, location, orientation, weather exposure, build quality and maintenance.

Any variation in the as-built work from the consent and relevant technical information should be noted, especially where these may have contributed to leaks and consequent damage.

Common areas of weathertightness risk features in a building are illustrated in **Figure 2** and described in **Table 1.** This is not an exhaustive summary. For example, retaining walls (tanking problems, poor drainage) or columns (inadequate top flashings or bottom clearances) may also be problematic.

After a general assessment of the building, any high-risk design features can be investigated in greater detail. Areas such as head flashing projections, cladding base details and clearances, apron flashings with kickouts and sealing of penetrations can indicate both the quality of workmanship and how well the designers and builders have understood detailing for weathertightness.

Figure 2: Common areas of weathertightness risk

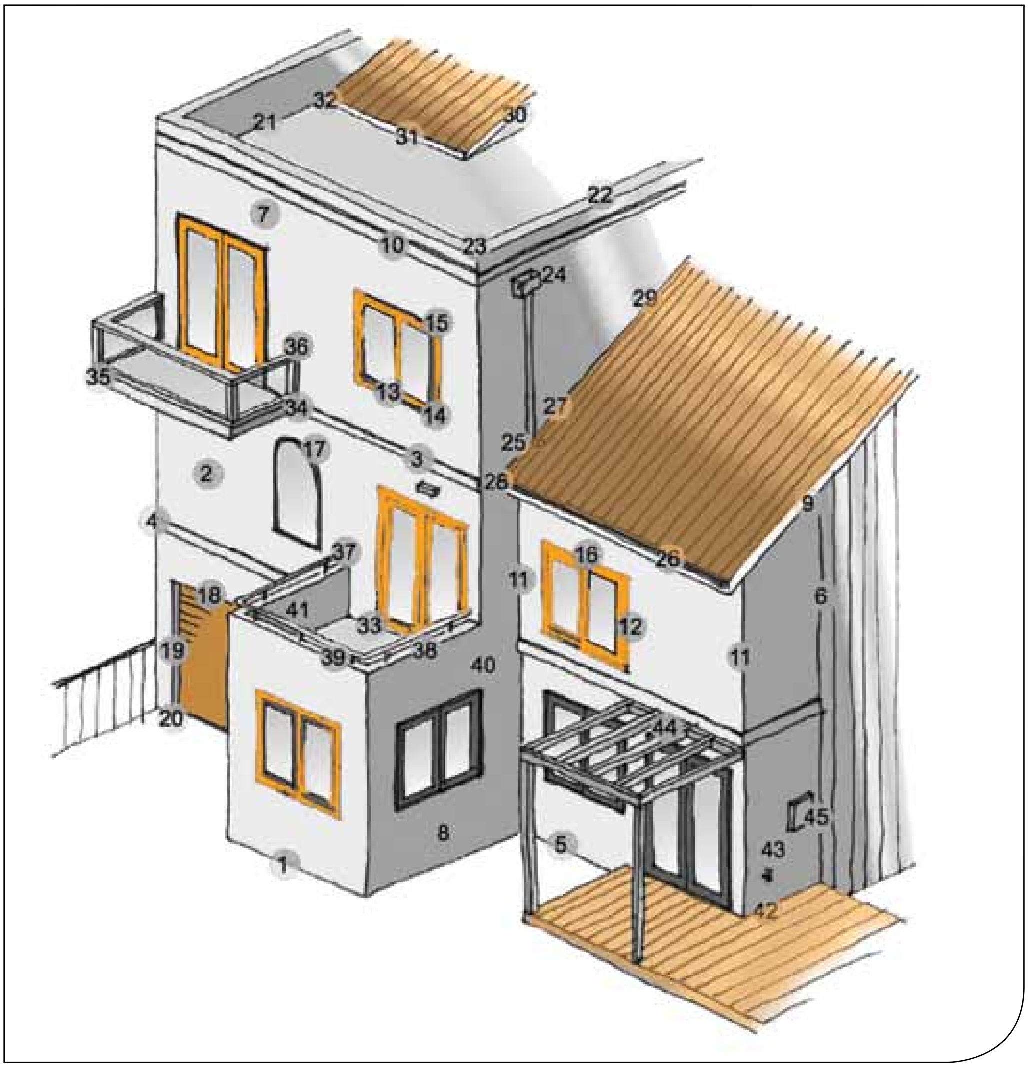


Table 1: Common areas of weathertightness risk

	Description	Potential deficiencies
	Cladding – general	
1	Base clearances	Inadequate cladding clearance (to ground, paving or decks) and fall away from building perimeter Insufficient floor height above ground, paving or decks
2	Body of cladding	Cracking
	Vertical control joints	Lack of or poor control joints
3	Horizontal and inter-storey control joints	No control joints, lack of flashings at joints Poor overlaps, flashing traps moisture
4	Horizontal joints – corners	Gaps, poor seals, no soakers
5	Cladding base	No anti-capillary offset/poor overlap No plaster drip edge Inadequate ground clearance
6	Inter-cladding junctions	No back-flashing, scribers etc
7	Sheet joints	Joints cracking/pouting, nails popping Joints lining up with window jambs
8	Material quality	Sub-standard solid plaster, reinforcing placement incorrect Unsuitable weatherboard profiles for the conditions
		Waterproof paint coating/sealer defects, lack of maintenance
9	Cladding top	Poor barge flashings Inadequate overlap/no drip edge Unsealed behind fascias or embedded
10	Decorative bands	Unsealed fibre-cement under bands, lack of inter-storey flashing under bands Flat top/cracks
11	Corners	No back-flashing, scribers etc
	Windows/doors	
12	Jambs	Cladding unsealed under jamb flanges
		No jamb flashings where needed
13	Sills	No drainage gap at sill flashing
		No/inadequate flashing or flexible flashing tape if applicable
14	Sill/jamb junctions	Poor seals/no soakers where needed No sill flashing turn-ups
15	Head/jamb junctions	Inadequate/unsealed head projection No turn-ups to the ends of head flashings
16	Heads	Lack of clearance from cladding to flashing Inadequate head flashing Flashing installed over wall underlay
17	Curved/raked heads	Inadequate head/jamb junctions

	Description	Potential deficiencies
18	Garage heads	No head flashing, no drip edge
19	Garage jambs	Unsealed/unflashed jamb liners
20	Garage jambs – bottom	Insufficient clearance from paving
	Roofs	
21	Parapet/roof junctions	Inadequate flashings
22	Parapet tops	No capping, flat top, top fixings
23	Parapet tops – corners	Poor capping joints
24	Rainwater outlets	Inadequately weatherproofed scuppers Lack of or inadequate overflow provisions
		Inadequately sized gutters – internal or external
25	Downpipe spreaders	Lack of or inadequate spreaders
26	Roof edge/gutter	Inadequate overhang stop-ends/turn-downs, gaps etc Building paper not overlapping gutters and fascias
27	Wall/roof apron flashings	Inadequate upstands/overlaps
28	Apron flashing – bottom	No kickout, poor sealant application, gaps, bare fibre-cement/exposed framing etc
		Gutters/fascias buried within cladding plaster/finishes
29	Roof/wall clearance	Inadequate clearance to apron
30	Other roof flashings	Inadequate overlaps, poor sealant application
31	Inter-roof claddings	Inadequate overlaps, poor sealant application Roof pitch too low, or inadequate falls to decking
32	Inter-roof/wall junctions	Inadequate flashings
	Decks	
33	Solid (enclosed) deck floor/wall junctions Solid deck surface	Poor cladding clearance, inadequate overlaps or upstands, capillary gaps, inadequate threshold clearance Inadequate falls and drainage, membrane damage, failing joints, poor substrate fixings
34	Solid (enclosed) deck edge/wall junctions	Inadequate flashings, poor upstand height
35	Open balustrade – solid deck perimeter	Poor membrane overlaps
		Balustrade penetrations
36	Open balustrade/wall junction	Unsealed fixings
37	Clad (enclosed) balustrade/ wall junction	No saddle flashings
38	Clad balustrade top	No slope to tops
		No capping
		Poor capping/capping joints
39	Clad balustrade – handrail fixings	Handrail penetrations through tops or horizontal surfaces
40	Clad balustrade – drainage/ overflows	Inadequate overflow/drainage, outlets too high, membrane not sealed to outlets
		Inadequate fall

	Description	Potential deficiencies
41	Clad balustrade/deck junction	Poor cladding clearance above deck Inadequate overlaps, capillary gaps
42	Timber slat decking/wall junctions	No drainage gaps Decking buried within cladding plaster/finishes
	Penetrations	
43	Pipe penetrations, cable entry	Poor seals
44	Pergolas, beams etc	No flashings, cladding not sealed behind fixings, fixings penetrating cladding
45	Meterboxes/grilles etc	No top flashings Poor sealant application/gaps/cracks etc

1.2.4 Monolithic wall claddings

There are a number of common problem areas to particularly look out for when investigating monolithic wall claddings.

Monolithic wall claddings generally

- Lack of, or inadequate kickouts to apron flashings terminating within wall
- Poor detailing at abutments (lack of saddle flashings)
- Lack of clearance to ground level
- Failed or poorly maintained waterproofing coatings and joints
- Impact damage to coating or backing sheets
- Wicking of water behind cladding
- Junctions that rely on paint, texture coating or incorrectly applied sealant to seal window facings to claddings
- Lack of ongoing, proper maintenance

Other factors particular to flush-finished fibre-cement

- Cladding application, including joints, junctions, flashings, not in accordance with manufacturer's specifications
- Framing and/or backing sheet with moisture content too high at time of construction
- Lack of adequate control joints – typically these should be at 5.4 m centres vertically and at the inter-storey level
- Sheet joints not located over solid framing or not made away from line of window or door jambs
- Unfinished joints, or uncoated fibre-cement behind fascias, barge boards, bands or other trim
- Poor application of stopping and flushing, and of textured coatings
- Back and edges of fibre-cement left unsealed, for example at joints, edges, penetrations
- Dark paint colours

Other factors particular to stucco

- Lack of continuous foundation
- Lack of adequate framing support
- Lack of adequate backing or lack of slip layer
- Reinforcing not properly spaced off backing or fixed to framing
- Reinforcement fixings penetrating membrane on sloping surfaces
- Reinforcement corroding due to inadequate thickness of galvanising
- Lack of adequate control joints – these should be installed at 4 m maximum spacing, including horizontal joints at inter-storey floor levels and vertical joints at the sides of openings
- Substandard plaster mix including:
  - sand in mix not clean, sharp and well graded
  - incorrect additives, or combinations of incompatible additives
- Plaster not applied evenly or thinner than the required 21 mm thickness
- Insufficient curing

Other factors particular to EIFS

- No back-blocking for fixings or penetrations
- Cladding application, including joints, junctions, flashings, not in accordance with manufacturer's specifications
- Lack of control joints
- Corrosion of fixings
- Dark paint colours
- Failure of paint and textured coating systems

STEP 1: SUMMARY OF INFORMATION TO COLLECT

- ◯ List of issues reported by the owner and/or occupants
- ◯ Description of current and recent weather conditions
- ◯ Relevant construction documentation and manufacturers' information
- ◯ Relevant reports and documents by other experts
- ◯ Photos of the building elevations and design risk features
- ◯ Photos and description of visual evidence of leakage
- ◯ Photos and description of damage
- ◯ Record of any health and safety issues

Step 2 – Non-invasive investigation

Step 2 – Non-invasive investigation

The aim of non-invasive investigation is to identify areas of potential water ingress.

During this stage of the investigation, the assessor should start to consider possible causes of moisture ingress and keep questioning any assumptions. Moisture travel paths should be considered. Problems can occur remotely from leak sources, so it is important to allow for the likelihood that there may be evidence of moisture in unexpected positions and/or evidence may be concealed.

The typical process is to:

- look for risk features and evidence of leaks
- evaluate the area surrounding any moisture ingress
- identify areas for more detailed examination.

Appendix III provides a summary of tools that will be useful during the investigation.

2.1 MOISTURE DETECTION

A capacitance moisture meter is useful for checking risk areas identified during the visual investigation and to identify areas for further exploration and invasive examination. It is best used from the outside where it is more likely to detect moisture directly behind the cladding, but may also be used within the building on inside surfaces of exterior walls.

However, capacitance moisture meter readings should be treated as indicative only, as they do not measure actual moisture contents. They are comparative and therefore only give an indication of where to consider invasive examination. They are also subject to a number of limitations which are described in Appendix III.

A number of other tools for checking moisture presence are described in Appendix III. These include:

- infra red cameras
- relative humidity sensors
- microwave meters.

2.2 WATER INGRESS PATH IDENTIFICATION

Indications of water damage, such as stains and cracks in the cladding, are often the starting point for tracking the water and moisture path, keeping in mind that water movement paths can be complex and may not be immediately obvious. For example, internal building elements such as bottom plates and framing dwangs can inhibit and/or redirect water flow towards unexpected locations in the building structure.

Dyed water testing is a common tool for identifying leakage paths and helps identify causes of the problem. Results can be easily photographed. Materials that are highly absorbent will cause different water movement behaviour from materials that are repellent. Care is needed in using this method as overflow of the dyed water can stain furnishings and fittings.

Damage in a particular location may be caused by more than one leak. Using different fluorescent dyed water colours can help isolate leak locations or contributing leaks. Confirmation of leak paths may not be available until cut-outs are made.

2.3 RECORDS

The assessor should keep clear records of the investigation, findings, site notes and photographs for future reference and inclusion in the report, as required. Photographs of a minimum of three megapixels will normally suffice and automatic camera date and time stamps will assist in organising photos later on.

STEP 2: SUMMARY OF INFORMATION TO COLLECT

- ◯ Notes of capacitance meter readings for reference
- ◯ Records of any other moisture readings with their locations
- ◯ Indications from dye water testing with location photos
- ◯ Results from any other non-invasive investigation
- ◯ Records and photographs

Step 3 – Invasive investigation

Step 3 – Invasive investigation

The aim of invasive investigation is to locate and confirm the causes of leaks, to start to identify the extent of damage and begin to detect what parts of the framing may be affected by moulds, fungal infection and decay.

Appendix III includes detailed information on various tools and methods for invasive investigation and how to apply them.

3.1 MOISTURE CONTENT TESTING

It is normal for the moisture content of timber framing in buildings to vary with the seasons and according to the degree of enclosure of the framing and its location in the building. The indicative nature of site-recorded moisture readings means that the particular circumstances on site at the time of the investigation need to be considered, such as recent weather conditions. For more information, refer to Appendix II.

3.1.1 Electrical resistance moisture meters

Electrical resistance moisture meters are the most common tool for taking readings in areas of suspected water ingress.

It is often necessary to take readings in suspected or high-risk locations even where there have not been any abnormal capacitance readings.

Resistance meter readings are indicative to some degree and should be treated as just another step in the diagnostic process. The readings should be noted and used comparatively only to indicate possible moisture ingress for further invasive examination.

It is usual to record just the actual meter readings on the day. In most situations it is too complex to try to reconcile corrections on site for temperature variations, treatment type or for timber species that may change from place to place within the building and that are usually unknown on site at the time of the investigation.

3.1.2 False negative or misleading moisture readings

Moisture content will vary over time depending on the source and frequency of water ingress.

- Circumstances such as long periods of dry or hot weather, particularly when combined with a type of construction that aids drying, or repairs, can cause previously wet and decaying timber to lose much of its moisture content, resulting in false or misleadingly low readings in leaking buildings.
- Low readings in leaking buildings can also be due to decayed timber that has shrunk away from a leak path and is no longer wet.

Conversely, some circumstances may result in misleadingly high readings, for example:

- if the probe insulation is damaged, or wet through, a partial short circuit occurs and the meter registers a lower resistance circuit through wet plasterboard, cladding or other material – this is a particular risk with driven probes
- if the measurements are made very close to the external surface of framing that is subject to condensation – this is a risk with short probes.

Any of these circumstances can result in 'false negative' or misleading moisture content readings, even though advanced levels of decay may actually exist. Assessors should look for subtle variations in moisture contents, even if readings are within acceptably dry limits.

3.1.3 Control points

Moisture readings are recorded as percentages of moisture by weight in the timber in comparison with an appropriate control point on the building. The control point is a point of reference that is highly unlikely to be affected by moisture ingress, for example a suitable location might be beneath sheltered eaves or in a porch. If necessary, a separate control point should be used on each elevation.

Readings from a control point provide the equilibrium moisture content as a basis to reference against. The moisture content will typically be in the range of 9–14 percent at these control points.

3.1.4 Moisture content thresholds

To help clarify the significance of moisture readings, it is useful to work to a range of moisture content thresholds. These should be used consistently throughout the diagnosis and in the subsequent report.

Appendix II lists typical moisture readings that are reflective of industry experience and how they should be interpreted in terms of timber decay.

3.1.5 Different timber species

It is not usually necessary to correct on-site moisture content readings for timber species, as it is the relative values compared with the control point reading that are important. This does however assume that all timber in the building has had the same treatment (or lack of treatment) and that environmental factors are the same during testing.

3.2 TIMBER DECAY TESTING

There are a number of useful site techniques for detecting timber decay. Results should be confirmed by laboratory testing with representative samples.

- The drilling process even prior to inserting the meter probes can provide useful information about the state of the timber, such as wetness, smell, colour, decay or hardness.
  - Sometimes, the drill may appear to have missed the stud or bottom plate altogether, but where examination of the drill bit shows that the drill position is correct, this indicates the timber is so decayed that it has practically no resistance to the drill bit.
  - The nature of the timber drillings can often give a good indication of moisture content and degree of decay, particularly in comparison with drillings from a dry, undamaged control sample. However, this must always be checked by taking sufficient samples of other wood for laboratory testing.
- Probing timber with a sharp tool such as a chisel: if the timber breaks off into short splinters ('brashness test') when levered by the probe, this is usually an indication of decay and loss of strength. Softness of the timber is also a useful indicator of decay (although juvenile heartwood may be soft irrespective of the presence of decay).
- Striking the timber with a hammer or similar: a soft and dull sound from a larger timber member, or a change in note along a length of timber, might indicate decay.

A number of other methods for timber decay testing are described in Appendix III: Investigative Tools and Practices, including:

- chemical indicators (for timber treatment identification)
- microscopy
- air sampling.

3.3 RECORDS

Records should be kept of moisture readings and their locations, marked up on an elevation, photograph or sketch drawing as an interim observations map.

If a theory for a likely leak path emerges, it is useful to show where the leak may have occurred, where the deficiency may have occurred on the particular elevation, how the moisture may have travelled through the structure, and what damage was caused. Photos can support the hypothesis and can be used in the written report.

STEP 3: SUMMARY OF INFORMATION TO COLLECT

- ◯ Elevations marked up with control points and relevant moisture meter readings
- ◯ Photos of timber testing locations (wide angle and close-up) with notes
- ◯ Notes on observed timber decay including any collected test samples or timber drillings (with sample identification, location sketches/photos, etc)
- ◯ Notes on defects and likely water flow paths, based on evidence gathered so far

Step 4 – Destructive investigation: cut-outs and samples

Step 4 – Destructive investigation: cut-outs and samples

The aim of destructive investigation is to confirm areas of suspected decay and moisture ingress/paths, and clarify construction detailing. It also allows access for sample collecting.

Destructive investigation involves cutting out sections of existing wall cladding (and sometimes removing internal linings) and most often will follow invasive moisture testing.

While destructive investigation aims to determine the real extent of decay, the assessor should be aware that not all decay can be easily identified – it may exist where the timber appears normal, or can be hidden, for example behind boundary joists.

Timber decay and mould identification are complex aspects of the diagnostic process. Samples should be examined under a microscope so that the type and extent of decay can be accurately determined and the appropriate remedial action developed. It is therefore important to work closely with a specialist laboratory that can advise on a number of significant aspects of the diagnosis, to help to guide the remediation repair recommendations, including:

- the type and extent of mould and decay and the presence, type and retention levels of timber preservative
- types of hazardous moulds, micro-organisms, etc
- how quickly decay will continue to develop
- how much framing needs replacement, the appropriateness of in situ preservative and the type recommended.

Often, further timber and other material samples will be sent for laboratory analysis as the building is opened up during the remediation work.

4.1 HEALTH AND SAFETY

It can be difficult to assess the potential for adverse health effects from mould and other micro-organisms (for example, actinomycetes and bacteria) and their by-products, as this can depend on the amount of affected material and its location, and the type of micro-organisms. It is advisable to obtain as much information as possible from all sources, keep people informed of potential risks and seek expert advice.

When taking samples:

- suitable protective equipment including appropriate breathing masks and gloves must be worn
- mould and fungi should be disturbed as little as possible. For example, stachybotrys atra is far more dangerous when it has dried out and the spores readily become airborne. When wet, the spores tend to stick together and are less likely to be breathed in by the building user

- cladding should be removed from the outside of the building rather than from the inside wherever possible, to allow any potentially dangerous fungi such as stachybotrys to be released into the atmosphere rather than inside the house
- any voids that may have been opened up as part of the investigation process need to be carefully sealed off.

4.1.1 Keeping an overall perspective

Subject to the terms of the report commission, it may not be cost-effective to carry out further detailed investigation if it appears likely at an early stage that full re-cladding will be needed. This might happen when there is a combination of untreated timber, a defective cladding system, widespread leaking, and widespread damage. In such cases, ongoing and detailed checking or laboratory analysis of any remaining timber would be far more practical during the subsequent repair process once cladding has been removed.

Conversely, if there appear to be few leaks and little damage, then it is particularly important to carry out sufficient testing to ensure any recommendations for limited repair will fix the problem and meet the Building Code. This would include taking timber samples for laboratory analysis if there is uncertainty about the type and nature of framing treatment.

4.2 CUT-OUTS

Destructive investigation involves making cut-outs in the cladding (or in some cases internal lining) to:

- confirm the results of timber drilling
- check underlying construction details and materials
- confirm leak paths and establish the extent of damage
- confirm whether apparent defects have led to actual damage
- check whether repeated details are defective
- take samples of timber and other materials to send for laboratory analysis.

There are no practical rules or 'square metre rates' for the number of cut-outs to take. Generally, cut-outs should only be made when there is reasonable probability of obtaining good evidence of the damage or of the deficiency which caused the damage.

When a cut-out is needed, a sheltered location to minimise further damage to the building is preferable.

Most owners will want to minimise cut-out sizes. Sometimes it is sufficient to use a keyhole saw (approx 100 mm diameter), which allows a neat patch repair. However, larger holes (up to A4 size) are often necessary for a number of reasons, such as following the leak path, determining the extent of damage, or checking an as-built detail.

4.2.1 Temporary patches

Cut-outs inevitably damage the wall cladding. Temporary cover patches need to be prepared and applied, as it is seldom possible to re-use the removed cladding.

The building owner should be made aware that any cladding that has had temporary patches will need proper repairs and should be made weathertight as soon as possible.

4.3 SAMPLES

Samples of timber and/or mould from the cut-out should be taken for analysis. There are no predetermined rules for the number of laboratory samples to take as the size and nature of sampling depends on the situation being assessed and the forensic information required. If the aim is to determine the length of time that the building has been leaking at a particular location, it may be important to send a sample from a clearly wet area and one from a reliably dry area.

Other factors which influence the decision as to how many and where samples should be taken include:

- whether framing is known to be treated
- the estimated length of time the timber has been subject to excessive moisture
- the extent of decay assessed from the on-site investigation so far
- the information available from drilling and other on-site testing
- whether representative sampling will suffice where the same defects are repeated elsewhere on the building
- whether either a full reclad or targeted repairs seems the more likely remediation option
- the costs of returning for more samples at a later date if assumptions prove incorrect
- whether initial judgements on decay are confirmed by laboratory analysis.

Ultimately, the decision on whether more cut-outs and samples are required rests on whether the samples taken will provide sufficient evidence to support the hypothesis for the cause of the weathertightness defects in the report.

A cut-out table that cross-references to the relevant elevations and photos is most useful for later analysis. This should show where cladding cut-outs and laboratory samples were taken from and record observations.

4.3.1 Size and nature of samples

A sample of surface mould can be taken using adhesive tape. A piece of sticky tape pressed down on the mould or fungi and transferred to a grease-proof paper envelope can be sufficient for laboratory analysis.

However, more useful forensic information can be obtained by sending a sample of the actual material to the laboratory for analysis (for example, building paper or plaster board) with the mould attached.

Normally a 100 mm length of 100 mm x 50 mm framing will maximise the potential forensic information. However, analysis of very small samples may be possible. Augur drill fragments (using a slow speed wide/flat-ended auger bit) are the smallest size of sample that could be collected. Hole saw cores (15–50 mm) are preferable. Chiselled samples can also be used. Small samples of this type minimise the damage to the cladding.

It is important to include samples of the timber that is considered to be least decayed to provide benchmarks.

4.3.2 Photographs

When sending samples to the laboratory, it is helpful to provide photographs showing where each sample has come from. Photographs from both close up and further away are useful to show the relative locations of samples on the building.

Photographs should also be provided that give an overall perspective of the type of building under investigation (such as showing the elevations, cladding type, junction details), to assist with the forensic analysis of samples and interpretation of test results.

4.3.3 Record investigation maps/drawings

A record of where cut-outs were made and laboratory samples taken from, and that cross-references to the relevant elevations and photos, is useful for later reference and analysis and for inclusion in the report.

4.4 IDENTIFYING TIMBER TREATMENT

Site testing for boron or copper-based preservatives can have some success if accepted procedures are followed, although the most reliable boron spot test is highly toxic and generally unsuitable for site testing.

Boron spot tests can give false positive readings. These are very common if only old surfaces are tested, leading to untreated wood being misdiagnosed as H1 or H1.2. In situ treatment can also be confused as being H1 or H1.2.

There is no reliable on-site test for H1.2 LOSP and H3.1 LOSP tin, so test samples for oven-drying are required. H1 permethrin and H1.2 permethrin plus IPBC cannot be tested using rapid spot tests. More costly and time-consuming (one to two weeks) quantitative laboratory analysis is required.

For more information, refer to Appendix III.

4.4.1 Samples of untreated timber

The use of untreated kiln-dried timber for external wall framing was common from 1996 to 2004. LOSP H1 treated timber without a fungicide became common from 1992 and can be considered the equivalent of untreated timber.

If on-site testing indicates that timber is untreated or LOSP H1 and decay is widespread, only a few samples may be necessary, as it is likely that a full reclad and major timber replacement will be needed. In such cases, the main reason for sampling will be to ensure the building owner has sufficient evidence to support the need for a reclad. Reasonable evidence of untreated timber includes markings on the timber and/or spot tests. The laboratory analysis can confirm that the timber is untreated and also the extent of decay.

An accurate record of sample locations should be kept to help inform the recommendations for the extent of any timber replacement.

4.4.2 Samples of treated timber

More samples may be needed for treated timber. However, if treated timber shows widespread decay due to leaks over a long time, a full reclad and major timber replacement may be inevitable and the assessor may choose to take fewer samples. Again, sample locations should be recorded to help inform recommendations for timber replacement or in situ treatment.

If leaking is relatively isolated and there is limited decay, targeted repairs may be an option. In this case, more samples may be required to determine the extent of the decay, taking into account the rule-of-thumb practice that all timber within one metre of the outer limit of the decay must be removed unless laboratory tests on samples taken inside this distance show no decay.

4.5 MOULDS AND FUNGI

The accurate analysis of moulds and other fungi found on site can only be undertaken by experienced laboratory specialists.

Some moulds and fungi can grow on almost any surface and many do not pose health risks. However, stachybotrys atra and some other types of mould are toxigenic and have been implicated in sick building syndrome. Stachybotrys atra is most commonly found on paper lining on gypsum paper board, fibre-cement board, building paper, and other cellulose-containing materials.

Some moulds (such as stachybotrys atra and chaetomium globossum) also cause decay in some situations. Specialist knowledge and experience is necessary to establish their significance in any given scenario.

Dormant fungi can be a problem. Decay fungi can remain dormant in dry timber for several years in some situations. Laboratory testing can determine if decay was recently active.

4.6 TYPES OF DECAY

While decay should be identified in the laboratory, the following is a general guide.

- Brown rots (at advanced stages) usually cause wood to lighten in colour prior to becoming dark brown, and to crack along and across the grain (although only once dry). When dry, very decayed timber will crumble to dust.
- White rots at well-advanced stages cause the timber to become lighter in colour and fibrous in texture without 'cross checking' along and across the grain.
- Dry rot is the common term for a brown rot, serpula lacrymans. This is relatively rare in New Zealand but it is a serious problem when found. It is difficult to distinguish from other brown rots, so field observations must be backed up with laboratory testing. Serpula lacrymans does not attack dry wood. It cannot decay wood at moisture content values below 18 percent. It can, however, move moisture over considerable distances from wet areas to dry areas via thick visible mycelial cords and can also spread across wide fronts on initially dry wood if very high atmospheric humidity prevails (above 85 percent and optimally close to 100 percent) and alkaline conditions are present (such as in fibre-cement base materials). If the air is moving and relative humidity values are no more than 75 percent, this is usually sufficient to retard dry rot growth across dry wood. The main concern with dry rot is that decay is very rapid once suitable conditions prevail.
- Wet rot refers collectively to all other brown and white rots.
- When conditions are particularly wet – moisture contents in excess of 60 percent – soft rot decay may occur. Timber affected by soft rot often shows little outward sign of decay – the classic softening is absent. Sometimes the timber may become a dirty grey to brown colour. When a sample at least the size of a matchstick is broken off, the fracture surface can sometimes look like a broken carrot (although juvenile wood without decay behaves in a similar fashion).

STEP 4: SUMMARY OF INFORMATION TO COLLECT

- ◯ Cut-out locations, with observations and photo references
- ◯ Records of suspected and evident extent of timber decay, or of any on-site testing for timber treatment
- ◯ Notes on likely decay, and causal links
- ◯ Extent of repeated defects and potential for future damage
- ◯ Timber and other material samples ready for laboratory analysis (with sample identification, locations sketches/photos, etc)
- ◯ Temporary patches installed over cut-outs
- ◯ Record of any health and safety issues

Step 5 – Defect analysis

STEP 5

Step 5 – Defect analysis

This section considers how to develop a robust theory for the cause of leaking, the extent of the resulting damage and the potential for future damage. This will form the basis of recommendations for remedial work.

There is no predetermined correlation between cause of moisture ingress, consequent damage and the required repairs. Each situation will have a variety of factors and the diagnosis needs to be on a case-by-case basis.

Significant field experience and specific in-depth training is required to draw valid conclusions from the evidence observed in steps 1 to 4 of the diagnosis.

5.1 ANALYSING THE EVIDENCE

The analysis stage should draw on evidence from all stages of the investigation so far, including:

- visual investigation – obvious signs of moisture entry inside and out; owner/occupier comments, overall building design and high risk features (for example parapets, complex joints and flashings, monolithic cladding, deck penetrations); any irregularities or complications identified from the consent documentation, manufacturer specifications, the as-built situation, build quality, etc
- non-invasive investigation – locations and extent of moisture ingress; preliminary conclusions on water paths and causal links within the building structure
- invasive and destructive testing – faulty construction joints, flashing failures, timber decay locations and water damage evidence; linkages between defect and damage; the extent of localised defects; the likelihood of systemic cladding defects, sampling and testing for potential future damage
- the results of laboratory tests and other specialist reports:
  - the presence and description of any mould/fungi
  - the potential extent of timber damage and subsequent extent of estimated replacement framing timber
  - the extent and type of timber treatment required for remediation.

5.1.1 Potential future damage

Leaks and/or damage may only be evident in isolated areas at the diagnosis stage. The assessor needs to make a judgment, based on the building features, evidence of leaking, moisture content readings and test results, as to whether water ingress and damage will also occur in similar risk areas in the future even if they are currently unaffected, such that the building would fail to meet the durability provisions of the New Zealand Building Code.

Within this guidance document, the terms 'potential damage' or 'potential future damage' refer to the consequences of those building defects:

- that are currently causing or contributing to leaks and that will *probably* cause damage in the future, or
- that are not yet causing leaks but are *probably* going to cause or contribute to leaks in the future and cause damage.

For the purposes of this guidance, 'probably' does not mean possibly – it is not enough that a defect might leak and cause damage. Whether or not something is probable will be a matter for the assessor to conclude and consider accordingly in developing the recommendations, based on the circumstances of the particular building and on the assessor's knowledge and experience of the consequences of weathertightness defects. Relevant factors to consider in deciding whether a defect may cause or contribute to water ingress resulting in damage include the level of exposure of the building and the design detailing of the defect.

Note – a building detail or design that is not causing or contributing to leaks but is non-compliant with the current Acceptable Solution is not necessarily indicative of potential future damage.

5.2 RESULTS

The analysis process should:

- identify the building details causing water ingress
- identify the extent of damaged building material
- determine the probability of potential future damage.

At this stage, the assessor should check that adequate moisture content readings and material samples have been taken to be assured of the accuracy of results, interpretations and analysis.

Depending on the circumstances, the conclusions from the analysis and the reasoning for the recommendations may need to be used as evidence in a court. It is therefore critical to have a clear and logical understanding of the causes of the leaks and damage and to have sufficient evidence recorded properly in both graphic and text format.

STEP 5: SUMMARY OF INFORMATION TO COLLECT

- ○ An overview of investigation readings, laboratory results, testing, etc
- ○ Understanding the building design risk features
- ○ Identifying the defects and leak paths linking to damage
- ○ Identifying the types of decay and extent of damage present and suspected
- ○ An assessment of potential for future leaks and damage
- ○ A schedule of relevant evidence

Step 6 – Developing the remediation recommendation

Step 6 – Developing the remediation recommendation

The assessor's remediation recommendation is to inform the building owner of the anticipated scope and cost of remedial works and should focus on repairs that are technically robust, cost-effective and meet the relevant statutory or regulatory requirements.

The assessor's brief for the report may be to also address other issues beyond technical weathertightness matters, for example structural, fire or energy efficiency issues.

The owner may separately engage a remediation designer upon receiving this completed diagnosis and report to explore options for improving their building, and develop the design and consent documentation. Remediation design is covered in a separate joint publication by the Department and BRANZ, *Weathertightness: Guide to Remediation Design*, referenced in Appendix V.

6.1 STRATEGIES

The fundamental constraint of the diagnostic process is that assessors have limited access to evidence. Further evidence may only be discovered once remediation works are underway with cladding sections removed and framing made visible. The assessor's conclusions and recommendations are necessarily based on a limited amount of information.

There are numerous technical building aspects to consider and balance when developing a remediation recommendation.

- Design risks – does the building have high-risk design features, for example complex joints or flashings?
- Cladding – what type of cladding is present?
- Workmanship – what is the quality of existing design detailing, of the build, and of any maintenance?
- Framing – is wall and roof framing treated to sufficient levels?
- Leaking – are leaks isolated and/or in consistent locations/patterns, are they systemic around the building?
- Damage: is damage limited or widespread? For how long has the building been leaking? Is hazardous mould present? How extensive is the damage beyond those locations examined?
- Potential damage – is there probability of future leaking and damage?

6.2 BALANCING RISK

Unlike a new design, where the designer has the freedom to manage risk through choice of design and materials, remediation work is restricted by the costs and complexity of repairing or replacing existing structures, materials and design features.

A remediation recommendation has to achieve Building Code compliance within these limitations.

It is useful to think of the 4Ds of weathertightness design (Deflection, Drainage, Drying and Durability) when considering design options. If the effectiveness of one or more of the 4Ds is compromised by the original design or the consequences of leaks, then increasing the effectiveness of the remaining 'Ds' can help balance such shortcomings and reduce the risk of a subsequent failure of the building.

6.3 RISK MATRIX ASSESSMENT

A risk matrix assessment for the weathertightness of a design, as set out in Acceptable Solution E2/AS1, may be helpful in the analysis and reporting. It can give an indication of the degree of weathertightness risk of each elevation or part-elevation for the particular wall cladding installation.

To be meaningful, the building needs to fall within the scope of NZS 3604. The scores should be calculated on individual elevations/wall planes and should not be applied so broadly that discrete high risk features are disregarded, such that isolated risks are lumped together and hidden in combined scores. It should be noted that not all elevations of a building will have the same risk score.

It may be that only parts of an elevation have risk scores that would require a cavity under E2/AS1. However, it is more practical to install a cavity to a whole elevation/wall plane than to parts of it. This is because when installing a single cladding type it is simpler and more practical for design detailing, flashing, consenting, fabrication/installation and construction, and it is aesthetically preferable to have uninterrupted wall planes.

6.4 RELEVANT BUILDING ACT 2004 REQUIREMENTS

As remediation involves repairs and reconstruction, which are alterations under the Building Act, the work must comply with the Building Code and any recommendation and estimate of costs in the diagnostic report will need to provide for this. The requirements of the Building Code and the need for building consent must be considered in light of the particular circumstances of the diagnosis.

Some remediation works may not require a building consent if the work fits within an exemption in Schedule 1 of the Building Act 2004. Generally, a building consent will be required for proposed remediation work:

- on a leaking building envelope which is less than 15 years old
- where failure of the building envelope is known to have occurred within 15 years of construction
- where any structural elements are being replaced due to leaks (for example, decayed timber framing)
- where repairs are being made to fire separations in non-detached houses.

Repairs and remediation works fall within the definition of 'alteration' in the Building Act 2004 and so section 112 of the Building Act will apply where a building consent is required. As a starting point, section 112(1) requires that after the alteration:

- the means of escape from fire and access for disabled persons must be upgraded as nearly is reasonably practicable to meet the current Building Code requirements, and

- the rest of the building must continue to comply with the other provisions of the Building Code to at least the same extent as before the weathertightness failure.

The Department's *Codewords 32 – October 2008* provides further information (referenced in Appendix V).

6.5 REMEDIATION OPTIONS

There are many complex factors and interactions at play within a leaking building that make it impossible for this guidance document to prescribe a remediation solution. However, there are some general circumstances where different approaches might be chosen.

Any recommendation depends on careful analysis of the evidence and situation, assessing the relative risks of possible solutions and weighing up their estimated cost benefits. The rationale for the recommendations needs to be clearly documented.

Demolishing the existing building and replacing with a new building may also be an option to consider in specific circumstances, such as in terms of overall cost-effectiveness. However, this falls outside the scope of this document.

6.5.1 In situ timber treatment

It is essential to follow the advice of an experienced remediation specialist or laboratory to confirm how much timber to remove and precisely what in situ treatment and conditions are recommended for the remaining timber.

The durability of undamaged framing that was either untreated or had low preservative levels will increase with in situ treatment, and this should be applied whenever this type of framing has been exposed.

Where timber is decayed, in situ treatment can be applied to at least three sides of each piece of framing (for example, with boron in glycol, or copper naphthenate in solvent), but this depends entirely on the type and extent of decay and the corresponding specialist advice. These treatments help to limit the growth of fungal decay but will not restore strength to damaged timber. It should be noted that in situ chemical application cannot effectively reach through decayed multiple or laminated timber members, and these will therefore require removal and replacement.

6.5.2 Targeted repair

A targeted or isolated repair may be appropriate for specific and localised shortcomings of the building envelope where the framing (including wall underlay, bolts and straps) in adjacent areas is unaffected. It may be appropriate in limited situations, such as for defective basement waterproofing, a faulty window and/or flashing installation, or leaking around a penetration.

If the framing is damaged, the cladding will need to be carefully removed to expose the full extent of decay.

Targeted repairs carry a high risk that further damage may be found during remedial repair work, necessitating a redesign and greater time and costs to complete the repair for the owner. The worst case scenario is that a targeted repair may not fully identify or fix the problem and that leaking and decay continue undetected, with the remediation team considered liable.

A recommendation for a targeted repair would need to be supported by a thorough inspection and investigation of the entire building on all elevations.

6.5.3 Partial reclad

A partial or limited reclad may be appropriate where:

- the investigation demonstrates that defects and/or damage are clearly confined to a particular elevation (or possibly one particular storey), or to sections of cladding between corners (ie, the evidence available and analysis show defects/damage are not systemic), and
- where resulting decay is confined to the framing in the immediate vicinity, and
- where the investigation has shown that adjacent areas of cladding and framing are free from defects and damage, and therefore from the potential for future damage.

Partial repairs may be successfully carried out to direct-fixed cladding systems in some limited circumstances, for example with overlapping and small unit cladding systems (such as weatherboards) where there are numerous joint lines to use as the boundary of the repair.

With flush-panel (or 'face-sealed') monolithic systems, it is more difficult to avoid failure at the boundaries of the repairs, for example, without introducing complicated flashings or express joints.

The assessor must be clear and confident about how junctions between the new and retained claddings are to be formed. This needs to be done without causing damage to the existing cladding, and so that sufficient laps can be achieved between new and existing underlays.

Decayed timber will need to be replaced, or treated in situ if it is shown to be structurally sound and is accessible. Any consequent removal and making good/reinstatement of linings, joinery, interior trim and finishes will need to be considered.

It is usual practice to remove windows/doors with the cladding, however the assessor needs to ascertain whether the failure is within the windows themselves, or at the junction between window and cladding, or both. Once windows are removed, this provides the added opportunity to reinstate/replace them and to install suitable flashings, sill support bars, air seals, etc as required.

The assessor should check carefully that a partial reclad solution:

- is cost-efficient compared with full recladding
- will deliver an effective remediation, and
- will address potential future damage.

6.5.4 Full reclad

The decision about how much defective cladding to remove to repair faults and to access damaged framing depends on various factors and their interactions, such as:

- the degree of risk posed by the existing building design features
- the type of cladding
- the quality of the detailing and build
- the framing treatment
- the leak patterns
- extent of the damage, and
- the potential for future leaks and damage.

Some examples of where recommendations for full recladding are most likely would be where the investigation demonstrates that:

- there are systemic defects (evidenced by leaks and damage) in the construction of the cladding system which can only be remedied by removal of all the faulty cladding, or
- the combination of repairs needed to remedy defects which have caused leaks and damage, and those defects that will probably cause future damage, can only be remedied by removing all the cladding, or
- the cost of full recladding is lower than targeted repairs and/or partial recladding to remedy isolated defects and replace or treat in situ framing that is decayed, and to remedy those defects that will probably cause future damage, or
- significant overall design changes are needed to reduce the building's weathertightness risk to an acceptable level.

In these circumstances, leaving portions of the faulty cladding system in place would be high risk. It would also make it difficult to effectively assess timber damage, replace decayed timber, treat any remaining sound timber, remove mould spores, and install the new cladding and flashing system.

Experience has shown that replacing only sections of affected timber can be very time and labour-intensive and it may be more cost-effective to replace with whole new frames. A quantity surveyor can advise on cost differences.

Where structural building elements are severely damaged throughout the building, a complete reclad would be needed to access the framing and fixings.

6.6 OTHER ISSUES TO CONSIDER

6.6.1 Structural problems

The report briefing needs to specify whether the recommendation should include rectifying any structural issues that are not related to weathertightness such as elements that were incorrectly designed or installed. In any case, it is essential that the report identifies any structural elements that may be a safety risk, for example inadequate bracing.

6.6.2 Other building defects

Other non-structural building defects may be identified during the diagnosis, such as:

- leaks in internal wet areas
- acoustic or fire separation problems in apartments
- safety problems with barriers or lack of handrails
- plumbing leaks
- unsafe electrical installations.

While these are not weathertightness issues, if they pose a risk to safety they will need to be addressed in the report. These matters should be brought to the building owner's attention as they could impact on any claims or legal proceedings the owner is involved in.

6.6.3 Incidental design impacts

For some remediation projects, the proposed remediation work can trigger a need to modify other aspects of building performance. For example, where direct-fixed EIFS cladding is to be replaced by EIFS on a cavity, the level of compliance with Clause H1 Energy Efficiency would be diminished by the added cavity. The insulation design would need to be recalculated to be no worse than before, with additional insulation to compensate, as required. Any of these items and their costings should be clearly included in the diagnostic report.

6.7 ESTIMATING THE COST OF REMEDIATION

Often the brief for the diagnostic report requires the anticipated costs for the remediation proposal to be included. The assessor therefore needs to produce a sufficiently itemised schedule of repairs for both current and any potential future damage to assist a quantity surveyor or experienced third party to prepare the cost estimate.

The assessor should clarify with the owner how the estimate should be presented in the report. It may be appropriate to include separate breakdowns of costs, for example for:

- current damage
- repairs already completed
- potential future damage
- work to meet the relevant legal requirements
- other non-weathertightness work
- building improvements (for example, for improved aesthetics/functionality)
- cost comparisons for different remediation options.

The cost estimate needs to specify what is included and what is excluded. The assessor should provide the quantity surveyor with as much detail as possible, including:

- relevant photographs, notes with marked up sketches and elevations
- the extent of framing for replacement, how much retained timber is to be treated in situ, whether windows are to be reinstated or replaced
- any requirements for managing existing ground levels/drainage/landscaping that encroach on the building

- whether membrane roofs/decks need replacement, other than new stainless steel screw fixings and roof vents, whether falls and drainage need to be corrected and whether the substrate and any roof framing should be replaced
- a thorough assessment of anticipated 'Preliminary and General' items, such as the ease of site access, entering/protecting neighbouring property or air space, allowances for scaffolding, propping, protection, on-site storage, site huts, reinstating adjacent linings, bathrooms/kitchens, making good, rubbish removal
- descriptions for the calculation of appropriate provisional sums for items of uncertainty, plus realistic contingencies.

Agree inclusions with the owner, for example:

- building consent and inspection fees
- preparation of detailed plans and specifications
- consultants' fees (designers, remediation specialists, and any others)
- laboratory tests and microscopic analyses, as required.

Agree any exclusions with the owner, for example:

- legal costs and expenses
- temporary accommodation, storage and relocation
- other costs incurred by the owner such as lost rent, borrowing costs, consequential losses, damages
- damage to interior fittings and fixtures (unless specifically stated)
- painting interior walls and ceilings (unless specifically stated)
- cost fluctuations.

STEP 6: SUMMARY OF ACTIONS AND INFORMATION

- ○ Develop a remediation recommendation, with appropriate rationale
- ○ Prepare the initial of schedule of works for the QS and commission the cost estimate, with relevant inclusions and cost benefit analyses (as required)
- ○ Identify non-weathertightness work
- ○ Collect and append supporting evidence
- ○ Collate material for the full diagnostic report, including the investigation and diagnosis, evidence, remediation recommendation and costings, together with a summary

Step 7 – The diagnostic report

STEP 7

Step 7 – The diagnostic report

This section provides a simple checklist as an example for a diagnostic report based on the generic investigation as described in this guidance document.

Some clients, however, may require only a short summary of pertinent issues and recommendations.

Some diagnostic reports, such as those for the Weathertight Homes Resolution Service (WHRS), may require additional information specific to their own commissioning instructions.

1 Report introduction

1.1 Description of the diagnostic project
1.2 Purpose of the report
1.3 Executive summary

2 Background information to the report

2.1 Description of property
2.2 Description of the building's construction
2.3 History of construction
2.4 People and organisations associated with the construction

3 Investigation – methodology

3.1 Pre-work and preliminary investigation
3.2 Site visits – dates, weather, meetings, details
3.3 Building investigation process and specialist equipment used
3.4 Owner/occupant comments and other information

4 Investigation – observations

4.1 Investigation maps/drawings – moisture readings, cut-outs, sampling locations
4.2 Observations and photographs

5 Investigation – analysis

5.1 Assessment of design risk features, leak paths and decay
5.2 Analysis of evidence from observations, laboratory results and other reports
5.3 Assessment of potential future leaking and damage
5.2 Risk matrix assessment
5.3 Health and safety
5.4 Non-weathertightness issues

6 Remediation recommendation

6.1 Remediation proposal summarised
6.2 Rationale for the recommendation
6.3 Estimated cost details for the recommended work

7 Summary conclusions

7.1 Repair proposal and estimated cost
7.2 Assessor statement of commission completion

8 Report: supporting documents and information

8.1 Legislation relevant to the building/repair
8.2 Assessor's qualifications and experience
8.3 Relevant Compliance Documents
8.4 Photographic records
8.5 Full estimate of repair costs
8.6 Certificate of Title
8.7 Explanation of particular items and terms used
8.8 Specialist reports
8.9 Manufacturers' literature and technical specifications
8.10 Owner's documents
8.11 Non-weathertightness building defects, deferred maintenance, etc – as applicable

Appendices

APPENDIX I: INDICATIVE HISTORY OF TIMBER TREATMENT IN NEW ZEALAND

Dates	Relevant activities
1930-40s	Native timber supplies running out.
1940s	Late in decade, State Advances Corporation concerned about insect attack on low quality timber. Use of tanalith approved.
1950s	DSIR investigates alternatives for treating pine. Decides on boron diffusion.
1955	Timber Preservation Authority (TPA) established. Only two grades of timber treatment initially: inside (protected) and outside (exposed).
1986	TPA releases list of treatments to achieve H1.
1987	TPA disbanded by Government. Industry establishes the New Zealand Timber Preservation Council Inc (TPC) to operate a quality assurance programme known as WOODmark®.
1988	MP 3640 reduces required level of Boron in H1 to 0.1% B.A.E (boric acid equivalent) at core of timber (core loading). Full sapwood penetration required. Primary risk identified as decay.
1990	MP 3602 – Boron treated timber must be kept at 24% or drier.
1992	MP 3640 amended – changes primary risk from decay to insect attack.
1993	MP 3640 amended again – core loading in dry timber reduced to 0.04% B.A.E to achieve H1.
Sept 1995	NZS 3602 amended to allow for kiln-dried untreated timber (KDUT) provided in situ moisture range is 18% or less (alternative solution at this stage).
Feb 1998	NZBC Acceptable Solution B2/AS1 amended to include NZS 3602: 1995. KDUT now part of Acceptable Solution (in situ moisture range to be 18% or less).
Dec 2003	NZS 3640 amended to include the new levels of timber treatment – H1.1, H1.2, H3.1, H3.2. Boron levels in H1.2 increased considerably to 0.4% B.A.E with some decay resistance. NZS 3602 republished as NZS 3602: 2003 (NZS 3602 works in conjunction with NZS 3640).
April 2004	Part 1 of NZS 3602: 2003 'Mandatory Requirements for Compliance with the Durability Provisions of Clause B2 of the New Zealand Building Code' becomes an Acceptable Solution after being referenced in B2/AS1. The previous Acceptable Solution, Part 1 of NZS 3602: 1995 (which allowed KDUT), continues to apply as an Acceptable Solution until 31 March 2005.
April 2011	H1.2 standardised for framing timber in B2/AS1.

Notes:

- The above timeframes are a guide only.
- 0.4% means for every 100 grams of oven dry timber, there has to be 0.4 grams of boron by weight.
- The level of boron retention started off high in the 1950s as the system was quite crude.
- In the 1980s, there was a world shortage of boric acid, so industry became more efficient and dropped the requirement to 0.1% in 1988.
- In April 1993, it was dropped again to 0.04% (measured at dry core) which is the level of most of the buildings affected by the leaking building syndrome. This means there was very little boron protection at the core of the timber, that is, at the centre of the cut (for example, at stud bottoms).
- It was difficult to be precise with boron treatment because of variables at both the initial uptake and in the residual levels after drying.

APPENDIX II: CRITICAL MOISTURE CONTENT OF TIMBER FRAMING

This appendix provides further information on understanding the implications and limitations of moisture content readings.

Moisture content readings presented in the broad bands below relate particularly to untreated radiata pine. The indicative nature of site-recorded moisture readings requires the assessor to consider the context and particular circumstances of the site at the time of investigation. This might include recent weather conditions, variations against the equilibrium moisture content (emc) at the control point, or false negatives.

For both resistance and capacitance meters, the assessor should not rely on any single reading or observation in isolation, as accurate assessment of moisture content is a progressive process. Low values should not be taken at face value, as moisture elevation caused by faults is often a passing event. For example, occurrences of dormant decay in concealed wood at moisture content values between 8–18 percent are common.

Any value above the expected or pre-recorded emc value should be taken as a sign to look further, and this includes values below 18 percent. The emc should be established by obtaining moisture content readings from a 'control point' or reference in external wall areas that are highly unlikely to be affected by faults (such as under protected eaves). For example, if background emc values are on average 11 percent, any value that is 3–5 percent above this (that is, 14–16 percent) would indicate a moisture problem worthy of consideration and possibly further exploration. It should be noted however that a range of factors, including preservatives, temperature, wood extractives, moulds and sapstain fungi, and wood species, can affect emc values.

Moisture content readings are only indicative

All moisture content thresholds used or referred to during investigation and remediation are indicative and not absolute. The generally recognised safe threshold for moisture content is 18 percent. Once decay is established, there is a probability that ongoing decay can occur close to 18 percent, but for uninfected wood, the moisture content conditions required for decay are closer to the fibre saturation point, probably 25–30 percent.

Fungi produce metabolic water during decomposition of wood and this local moisture may be undetectable with available resistance meters which do not pick up the micro-moisture percentage changes. Furthermore, moisture conditions in the outer 1–5 mm are sometimes higher than in deeper wood in situations that are marginal for decay, for example, where condensation occurs.

Moisture content bands

The recognised moisture content bands are as follows.

Up to 18 percent

- Moisture content readings in this range fall within the maximum allowable range for untreated radiata pine as per NZS 3602: 2003 for members protected from weather and in dry conditions.
- While moisture content of this level could indicate possible problems, it is generally considered that this level will not support timber decay.

18–24 percent

- Moisture content readings in this range indicate problems exist and excess moisture should be immediately corrected.
- Such levels must be considered a warning that remedial action is required to prevent future damage. Mould growth will be common in wall cavities.
- Once decay is established, there is a significant probability that ongoing decay can and will occur.

24 percent and above

- Readings of 24–30 percent within wall cavities are commonly associated with actual and often extensive damage.
- Moisture content of 24–35 percent will allow decay to initiate depending upon the treatment of the timber. However, once established, there is a significant probability that ongoing decay can occur in the 18–24 percent range.
- For uninfected timber, the moisture content conditions for decay initiation are closer to the fibre saturation point of 25–30 percent.
- Readings of 30–40 percent indicate inevitable decay caused by the availability of free moisture above fibre saturation point (approximately 29 percent in radiata pine, which is a commonly used framing timber).
- Moisture content of above 35 percent will almost certainly be harbouring decay fungi which will cause rapid deterioration of untreated timber, or timber from which the treatment has leached.
- Readings of 40–60 percent are optimal values for aggressive decay.

APPENDIX III: INVESTIGATIVE TOOLS AND PRACTICES

This appendix provides a brief overview of common diagnostic tools and practices in use in New Zealand at the time of publication. There are new systems and proprietary products continuously being developed.

Two areas of improvement that would be particularly beneficial for diagnostic technology would be:

- reducing the number of cut-outs that fail to yield subsequent evidence
- discovering areas of damage/moisture that are missed by current methods.

There is currently no 'silver bullet' for moisture (and decay) measurement that could replace capacitance and resistance-based meters as the main diagnostic devices in use, as these offer the best mix of value, usability and effectiveness.

An experienced assessor can bring significant benefit to the diagnosis of a leaking building through understanding the limits of current technology and correctly interpreting the technical results from their equipment.

Summary of diagnostic techniques in use		
	Often useful	**Occasionally useful**
Moisture	Capacitance meters Resistance meters Dye testing	Infra-red cameras Relative humidity sensors Microwave meters Oven drying
Decay	Chemical indicators (timber treatment) Microscopy	Brashness test Air sampling

The table below notes tools that may be used for buildings that are constructed with other than timber frames. The assessor needs to be aware of the limitations of each tool they use and factor those limitations into the assessment.

Tools for materials other than timber	
Moisture	Capacitance meters (not for metals) Dye testing Infra-red cameras Relative humidity sensors Microwave meters
Decay	Air sampling

Moisture detection tools that are often useful

Electrical capacitance meters

Electrical capacitance meters are inexpensive and non-invasive but may miss areas of high moisture that are found subsequently by other methods. They can be used on almost all types of materials with the exception of metals. The assessor needs to be familiar with the manufacturer's instructions, such as calibrating the meter for the particular material.

Capacitance meter readings should be used carefully and should not always be relied on. The readings should be treated as being relative and indicative only, as the numbers do not record moisture contents. Readings taken from capacitance meters are used for comparative purposes to give an indication on site where further investigation should focus.

Capacitance meters can scan externally or from inside the building. The following points on their use are prepared from the CIRIA publication, *Review of testing for moisture in building elements.*

- Ensure the material settings (for example, timber or concrete) of the meter are applicable to the material being scanned.
- The signal will not pass through metal material that may be located between the electrodes and the material being tested, such as metal lath, which can affect readings.
- If the surface is rough, the readings are likely to be low. In such cases, for 'soft' materials, it is helpful to apply some force to minimise the air gaps that affect the readings.
- Density variations within any given material substantially affect readings (for example, knots in timber). Where possible, tests should be made on representative areas.
- Direction of grain in the case of timber can affect readings; seek manufacturer's recommendations for specific information.
- Some screed additives or residues can affect readings and may give false readings.
- The meter will give reduced readings for a substrate through a thick coating.
- Elevated readings may be due to contaminants or certain additives.
- The meter response is non-linear with depth.

Capacitance meters are often completely ineffective when the cladding is thick, such as EIFS, as the meter is unable to scan to the depth of the framing timbers.

Electrical resistance-based meters

Electrical resistance-based moisture meters are both an established technology and a common way of assessing the moisture content of building materials in situ, especially wood.

There are three methods for obtaining timber moisture content readings.

- One-off measurement: the most common method is when measurement electrodes are inserted into the timber for the duration of a single measurement.
- Fixed-probes: electrodes are left in the timber and re-connected to the meter for another measurement at a later date.
- Continuous data acquisition: similar to the fixed probe method, the electrodes (often simply stainless steel nails) are left in situ with uploaded measurements at regular intervals via an automated logging system.

The following are points on their use.

- Ensure the meter is correctly and regularly calibrated.
- Follow the manufacturer's guidance regarding the operation of the resistance meter. Use sliding hammer electrodes with long insulated probes driven parallel to the grain.

- Ensure good electrical contact at the desired measurement location, keep the electrodes in good condition and particularly pay attention to the condition of any insulation on the electrodes.
- Consider the accuracy of the meter itself and especially how accurately the meter is reading the actual materials within the situation at that time (that is, timber species and treatment, temperature, the meter's accuracy range).
- If comparing readings for the *same* location at *different* times, temperature correction is necessary to make valid comparisons as temperature can significantly alter the resistance of timber.

The assessor should look for the relative differences between readings, such as 3–4 percent above the equilibrium moisture content rather than absolute moisture content readings.

The demand for technical correctness may be mitigated when using the results in a comparative manner or if the timber is clearly above fibre saturation. Users of the data need to be aware of the limitations.

Moisture detection tools that are occasionally useful

Infra-red (IR) cameras

Infra-red or thermal cameras are non-invasive tools that can support the reliability of the subsequent invasive investigation. They measure the heat emitted by surfaces and consequently they trace thermal differences. While not their primary function, the resultant images can sometimes be interpreted to locate moisture.

With low levels of moisture ingress, especially when hidden within a wall, the thermal patterns will be subtle and will require extra skill and experience for interpretation.

Numerous factors can lead to false impressions from the thermal images, such as these prepared with information from the Restoration Industry Association's *Cleaning and Restoration* magazine November 2003, 'Moisture Detection Using Surface Temperature Patterns' (L. Harriman).

- **Cold inside corners** – The corners of a room are inherently colder than the bulk of the room due to limited air flow (mixing), rather than moisture.
- **Sunlight/shadows** – Sunlight can heat the internal surface of a wall and partial shading can locally decrease the temperature. The resulting patterns from these factors can be confused with moisture.
- **Air conditioning** – Air from air conditioning systems can cause patterns which are highly suggestive of moisture.
- **Electrical heat sources** – The extra heat from electrical sources can generate misleading variations in temperature.
- **Air infiltration/exfiltration** – Air constantly flows into and out of walls. This can change the internal and surface temperatures.
- **Layers and gaps in the wall** – Moisture-related temperature differences can often be 'flattened-out' because the moisture is deep in the wall and not near the surface.
- **Ill-fitting thermal insulation in the walls** – Insulation gaps can lead to spots of higher or lower surface temperatures.
- **Surface materials** – While IR cameras detect radiation emitted from surfaces, different materials have different emissivities leading to differing readings in spite of those materials being at the same temperature.

The capability of the person using a thermal camera is just as important for avoiding misdiagnosis as the technical capability of the camera.

Relative humidity sensors

Hygrometers (or relative humidity (RH) sensors) can simply be placed in an air space, allowing humidity to be compared to humidity levels in other parts of the building. This is often useful where electrical resistance meters are not applicable, such as when the building has steel framing.

RH sensors provide readings that are purely comparative/indicative. They can be used to assess the effectiveness of cladding, coatings and ventilation in reducing moisture levels in construction materials and to check for condensation or high humidity in wall and roof systems or in basement construction.

Moisture content for material in the vicinity of the airspace can also be estimated using the humidity measurement. At a given relative humidity, a hygroscopic material will reach an equilibrium moisture content level given enough time. The general practice for a one-off reading is to drill a hole in the cladding and quickly seal the hole with duct tape. A nick is made in the tape so that the sensor tip can be placed in the hole. The humidity measurement is taken and compared to the ambient humidity in the vicinity of the hole (taken immediately prior to the hole reading) and other measurements from around the building.

Humidity sensors can form part of a long-term monitoring system that is implemented using a relatively new range of small self-contained logging systems, but they do require periodic recalibration. These units are very small and are simply programmed and installed, with information downloaded as required.

However, there is a trade-off decision to make: is it worthwhile to monitor a building when progress could be made more quickly with more invasive investigations?

Microwave meters

Microwave methods are mostly suited to flat surfaces which have a thickness in excess of the penetration depth of the microwave signal. They are not suited to the lightweight timber-framed wall construction used in the majority of residential buildings and are most suited to blockwork or concrete construction, such as in larger apartment-style or commercial buildings.

Similar to the capacitive methods used to scan walls, the microwave method also relies on the fact that water has a significantly higher dielectric constant than most building materials.

The signal from microwave meters penetrates the material by about 20–30 cm, therefore the building element under test needs to be at least this thick. Similar to when capacitive methods are used on materials other than timber, the measurements can only be taken as relative values. Metals can cause false readings due to reflections and the generation of standing waves, and this could be an issue when inspecting reinforced concrete.

Oven drying gravimetric method

This is a fundamental way to determine the amount of moisture in a hygroscopic material. For timber, the oven drying method is described in AS 1080.1: 1997.

While this standard is focused on assessing timber from lumber yards, the principles remain the same for the much smaller specimens taken from a building.

Although the oven drying method is relatively straightforward, the specimen needs to be taken to the oven in its 'as found' condition.

- Samples should be handled carefully at all stages including collection, transportation and processing.
- Samples should be kept in an airtight container in a cool, dry place.

Oven drying can be used to find and confirm the results from other tools and to find the actual moisture content when an assessor suspects a resistance meter reading may be false negative.

Treatment detection tools that are often useful

Chemical indicators

Chemical reagents are used to determine significant information about the timber under investigation (for example, whether it is sapwood, preservative treated, or decayed), however this section focuses on those used for testing preservative treatment.

- Boron – A relatively easy identification test exists for boron treatment and, when performed properly, its accuracy is comparable to a quantitative laboratory analysis. The reagent is the chromophore from the spice turmeric, used in conjunction with hydrochloric acid. When applied to the specimen, the colour will change to orange or red if boron is positive, or yellow or bronze if negative. However, alkaline materials can result in a false positive, such as when the framing is next to gypsum or masonry, so a cross-section of material is needed.
- Copper – The test for H3.2, H4 and H5 is easier to interpret because it uses a single reagent (rubienic acid) and it is specific to copper.
- Tin – The test for tin can also react with zinc (for example, nail plates) so can be open to misinterpretation.
- LOSP – There is currently no spot test to identify LOSP treatment and the only infallible way to identify it is to send samples to a laboratory for full chemical analysis. This requires a number of samples and a series of tests.

The first test would be a sapwood/heartwood test, followed by spot tests for boron, copper and possibly tin. Finally, destructive tests can ascertain the presence of LOSP. Even then, the results are only strictly applicable to that piece of timber.

Decay detection tools that are often useful

Microscopy

Microscopic laboratory analysis of fungi is the de facto method for decay identification, with a proven track record for success, but with the disadvantages of the time taken to obtain results and the cost of the analysis.

The wetting regime and the type of timber can result in different types of decay activity. By observing the decay, an understanding is gained about the moisture history of the piece of timber and an assessment of how much structural damage has been done to that sample.

It is important that the sample is representative of the rest of the framing timber. When collecting samples it is recommended that:

- most samples are taken from borderline areas, as there is no need to analyse obvious decay
- samples should ideally all be solid cores through the depth of the piece of timber.

Shavings from small drilled holes may be an attractive option because they are clean and quick. However they take longer to analyse and do not give as much information about the depth of decay activity through the section. Larger samples are more useful.

Surface fungi can be sampled by applying a strip of adhesive tape to the timber and then removing it.

Decay detection tools that are occasionally useful

Brashness test

This simple test consists of prying up some splinters of wood and observing the type of splintering which occurs. This is essentially a test for toughness, since sound wood generally produces a long, fibrous splinter, while decayed wood, which is characteristically brash, produces a short splinter which breaks easily across the grain. The brashness test should not be relied on as the sole means of identifying timber decay, but it may be of use to the assessor as an additional or 'on-the-spot' method.

Air sampling

Air analysis (including culturable methods) of wall spaces is only necessary where conventional moisture meters have failed to pick anything up but a problem is still suspected, such as in the height of a dry summer or with a steel-framed building. The focus of the method is on looking for concentrations of bacteria or fungi in the air (not the wood) that are indicative of moisture or moisture damage.

There are two kinds of analysis and each technique consists of a collection phase and an analysis phase:

- **the culturable method** requires an incubation phase prior to analysis to allow the fungi and bacteria to grow
- **the non-culturable spore trap method** is used to analyse a wider range of fungi than the culturable method, and is better suited to establishing whether stachybotrys is present.

Problems in the wall space may not be identified by sampling air from the occupied space, depending on the ventilation to/from the different areas. Also, high fungal counts from the living space do not automatically mean there is a problem within the structure itself.

Assessors can collect their own non-culturable samples using a small portable sampling pump: a small hole is drilled into the wall, into which a tube is placed that is used to suck the air sample out. Here the sample is collected in a cassette containing a gel-medium. The cassette is then sent to a laboratory for analysis by specialists.

The minimum number of samples for any case would be three – one for the area under investigation, one from an area that gives no concerns and the final sample should be from the outdoor environment that is well away from the structure.

APPENDIX IV: WORKED EXAMPLE OF A DIAGNOSTIC INVESTIGATION

This appendix provides an example of how a diagnostic investigation might proceed. It sets out an approach to examining one elevation, as illustrated in Figure 3, of a notional two-storey, stand-alone, timber-framed building. The sample uses the steps described in this document, and concludes with the defect analysis and summary outline of a recommended remediation for the subject elevation.

Note that this example focuses on just the one elevation, whereas a real world assessment would need to continue around the building. The aim of the example is to demonstrate the process of determining the extent of current and potential future damage to support the development of a recommendation for remediation.

Step 1 – Pre-site work and visual investigation

Information collected from the BCA records and the owner includes:

- building constructed during 2002
- high wind zone
- consented specification for untreated kiln-dried timber wall framing with H1 treated first floor joists
- manufacturers' information for the wall cladding and windows.

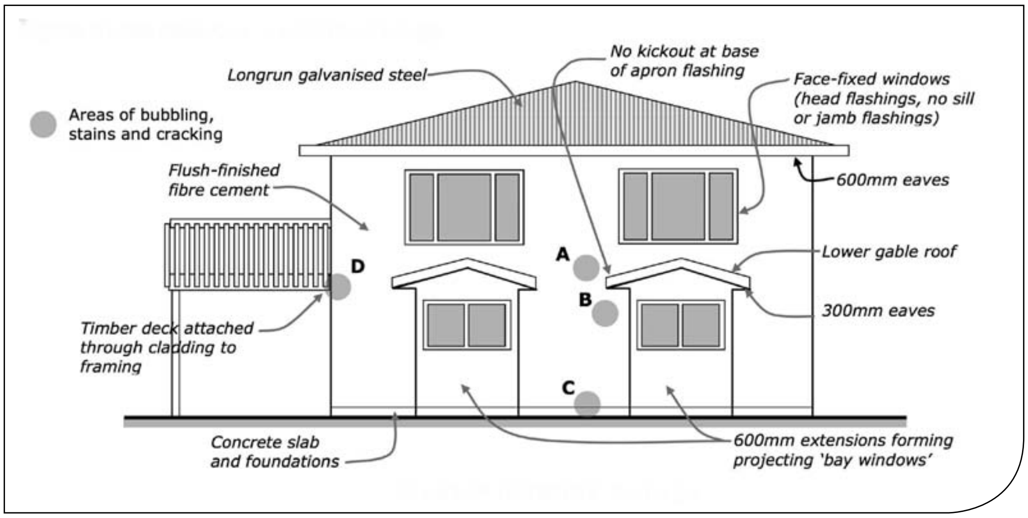
The site inspection was carried out in late January after three weeks of very dry weather.

An inspection of the interior indicated signs of water entry, stains and discolouration, some water-damaged window sills and skirting, and damp floor coverings around the door opening to the deck adjacent to the elevation under investigation.

The following high-risk design features were identified from the on-site observations:

- flush-finished, texture-coated fibre-cement wall cladding system with no visible inter-storey joint, with stains and cracks apparent
- windows face-fixed with metal head flashings but no sill or jamb flashings
- complex roof-to-wall intersections above the two bay windows
- apron flashings above the bay windows without any kickouts – sealant was used at the bottom of the flashings to prevent water entry, but appears to have failed at location A
- 600 mm eaves at upper roof level and 300 mm eaves to the bay windows
- timber slat deck, on adjacent elevation, fixed directly through the cladding with coach screws at first floor level.

Figure 3: Elevation with visible moisture damage



The cladding is showing signs of damage due to moisture ingress as follows:

- location A – cracking of cladding and paint bubbling at inter-storey level above bay window roof
- location B – cracking of cladding and paint bubbling below missing kickout flashing
- location C – nail popping and discolouration at bottom plate level directly below other defects – cladding is installed hard up against the foundation restricting drainage at bottom of sheet
- location D – cracking of paint and bubbling of paint at inter-storey level – adjacent to where the deck is fixed.

The occupants have noticed musty smells in the rooms on both levels of the elevation for the past four or five months. A builder who looked at the problems several months ago detected some possible water ingress at the kickouts of the bay windows and applied sealant around these points.

Step 2 – Non-invasive testing

Capacitance meter readings were taken on each side of the two upper storey windows, around the sills. The readings suggested these areas were sound and unaffected by moisture, however the recent dry weather could account for possible 'false negative' readings.

Further capacitance readings that were then taken over the elevation (concentrating on the four locations A, B, C and D as noted above) showed signs of damage, including:

- along jamb edges of the windows (where moisture may be entering due to lack of jamb flashings and poor sealing of the window jambs against the cladding)
- underneath all windows and particularly at the corners
- immediately below positions where bay window roof-to-wall apron flashings lack kickouts
- at the inter-storey joint level for the full width of the elevation
- at the timber deck-to-wall junctions
- at bottom plate level for the full perimeter, including areas where the cladding shows signs of moisture ingress.

Readings exceeding an indicative control point were found along the middle and left sections of the bottom plate. High readings were also found at the bottom of the left-hand external corner.

Dyed water was then injected under the bay window apron flashing (at A16) with dye traces subsequently found in location C at A6 (refer to Figure 4). Photographs of the results were recorded as evidence.

The capacitance meter readings, the dye water tests and the assessment of the design risk features indicate where to start invasive testing.

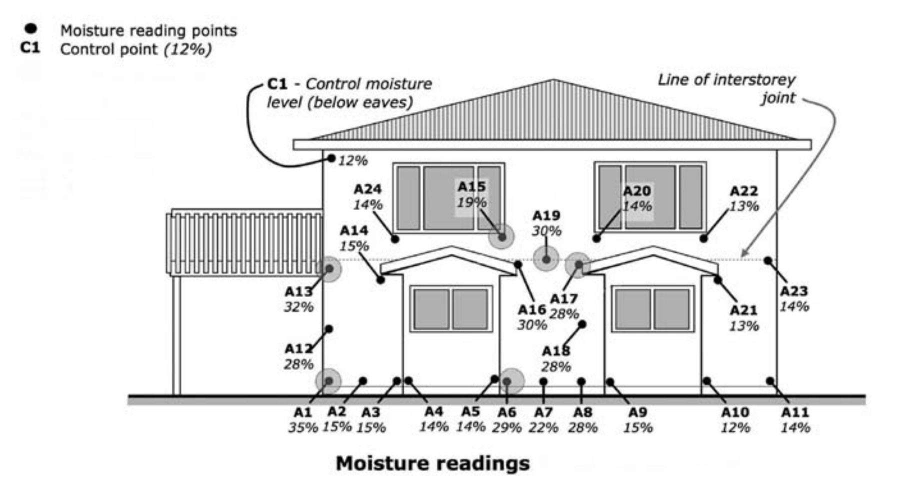
Step 3 – Invasive testing

A sheltered 'control point' beneath eaves was selected, as this location was considered unlikely to be affected by any faults or moisture ingress. The equilibrium moisture content (emc) reading at this control point was 12 percent.

The points chosen for electrical resistance readings were based on the indications so far of water penetration, damage observations and where capacitance readings were more than 3–4 percent above the emc. These locations were considered the most informative for identifying obvious points of moisture ingress and for assessing any damage.

Invasive electrical resistance moisture meter readings were taken in the framing timber in each of the locations shown in Figure 4 at three progressive depths, starting close to the exterior surface with the last reading in the approximate centre of the studs.

Figure 4: Moisture readings



Additional information was gained from the actual drilling for invasive moisture readings. The hardness of the timber could be estimated by the resistance of the drill compared with the control point. Similarly, the moistness, smell and nature (appearance and level of decay) of the drillings themselves gave clues to support the meter readings.

However, these results and readings were still treated as only indicative at this stage. Final conclusions were avoided until cut-outs had been made, the exposed timber inspected, samples taken and laboratory test results received.

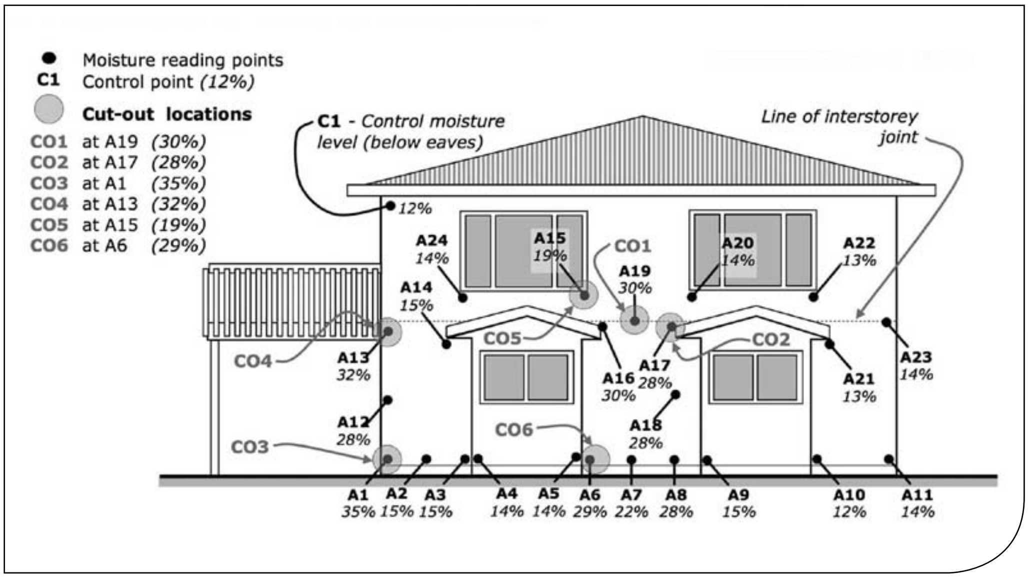
Step 4 – Destructive investigation: cut-outs and samples

Determining number and location of cut-outs

Cut-outs were taken at areas with different construction features and high moisture readings (more than 3–4 percent above the emc) to confirm the indicative results from the previous non-invasive and invasive testing. In this example, cut-outs were made at the locations shown in Figure 5.

Note: Too many cut-outs in a wall (particularly with monolithic cladding on direct-fixed, untreated frames as in this example) will damage the cladding and affect its ongoing weathering ability despite temporary patches. This itself can influence the repair recommendation. Thorough examination of one or two details repeated throughout a building can reveal sufficient information of leak causes and damage to support the decision to limit the number of further cut-outs necessary where the details recur.

Figure 5: Cut-out locations



In this example, as shown in Figure 5, the locations for cut-outs were selected as follows.

- CO1 – to expose the inter-storey joint detail (refer to location A) and confirm decay.
- CO2 – to confirm whether the apron flashing (location B) directed water into the wall rather than away from it, because there is no kickout on the actual flashing. The dye test had already indicated a moisture path from A16 to A6. There was no need to take cut-outs at A14, A16 or A21, as it was assumed that construction details would be similar.
- CO3, CO6 – to confirm the suspect cladding detail at the base of the wall (such as at location C) and resultant high moisture content and decay. As construction details and moisture readings are similar, it was unnecessary to make any more cut-outs at similar cladding base locations.
- CO4 – to confirm the inter-storey detailing and reveal any issues at the corner (location D). (Any leak issues from the deck/balustrade on the adjacent elevation are not included in this example.)
- CO5 – to check the elevated moisture content at A15 and to confirm how the underlying window sill-to-jamb junction was built.

The six cut-outs all indicate some timber decay. There are also low levels of mould, but the visual inspection so far cannot confirm any hazardous mould species without laboratory tests. Removing the cladding cut-outs showed a clear water flow path from the apron flashing over the bay window, behind the cladding and down into the framing. The inter-storey cladding joint had not been built in accordance with the manufacturer's specifications, as revealed by cut-out C01.

The primary causes of the leaks, so far, point to two main defects:

- insufficient detailing around the bay window apron flashings
- poor detailing of the inter-storey junction.

Leakage around the upper storey window sills shows only one area (A15) of elevated moisture with mould evidence. However, the recent dry weather could have allowed the timber moisture content to drop below recognised critical moisture levels at the other sills (A24, A20, A22), resulting in 'false negative' moisture readings.

So far there is evidence of high moisture readings, observed timber decay, poor inter-storey detailing, a face-sealed type of cladding and insufficient framing treatment specification.

Determining sampling location for analysis

In relation to overall costs involved in investigation and remediation work, the cost of analysing timber samples is relatively minor.

As some decay and associated effects (including discolouration of timber) are evident, the objective of taking timber or other samples is to determine the following.

- **Extent of decay** – samples were obtained from the fringes of visible decay, as it is important not to take timber samples from the middle of obvious decay.
- **Type of fungi present** – although the initial inspection did not indicate the presence of any obvious hazardous mould species, it is still important to confirm this with laboratory testing because of the potential health implications for the owners/occupants and because of implications for site safety during remediation construction. The mould and timber analysis can also provide useful information as to how long the moisture has been present and the type of decay.
- **Existence, level and type of timber treatment** – although the building consent documents indicate that untreated timber was used for all wall framing and H1 treated floor joists, this cannot be confirmed on site. Because this has important implications for the remediation strategies (whether either a full reclad or a more localised solution is needed), laboratory tests are needed to confirm treatment levels.
- **Timber species** – while the evidence suggests radiata pine framing was used, this needs to be tested. Some timber species are more resistant to decay than others and this can have implications for the recommended remediation strategy.

Collecting samples for analysis

The wall framing timber was specified as untreated, kiln-dried radiata pine. Therefore, sufficient timber samples were collected for laboratory analysis to cross-check the preservative and also for wood decay and to identify any fungus and mould. If moulds were evident, but timber decay was not clear, additional wood samples would have been necessary.

Included in these samples were one from CO5 (below the upper window) and one from the first floor timber joist at CO1. The floor joists were specified as H1 boron-treated timber (in contrast to the specified untreated wall framing), which has probably helped prevent decay, but this needs to be confirmed by the laboratory test results. For wall framing, a sample was taken from where decay appears to have started and another at what appear to be the limits of the extent of decay.

The laboratory analysis subsequently confirmed the initial on-site assessments and therefore no further timber or mould samples were necessary. If the laboratory analysis had contradicted these earlier assessments, then more sampling and testing would have been needed.

Step 5 – Defect analysis

From the investigation described already, together with the laboratory test results, a scenario of the moisture penetration and subsequent damage has been developed. Refer to Figure 6.

- Area 1 (between the bay windows) – refer to A6, A17, etc
  Initially water has entered the wall at the bottom of the apron flashing (cut-out CO2 revealed no kickout). The sealant that was added later on failed and water has leaked again behind the cladding.

  The resulting movement of timber and cladding has caused the deficient (non-draining) detail at the horizontal inter-storey joint to fail, causing additional cracking and moisture penetration.

  Water has then leaked down through the structure to the bottom plate level where moisture has been trapped due to the lack of drainage, causing damage to the framing timber. Water has then spread along the bottom plate, causing further damage.

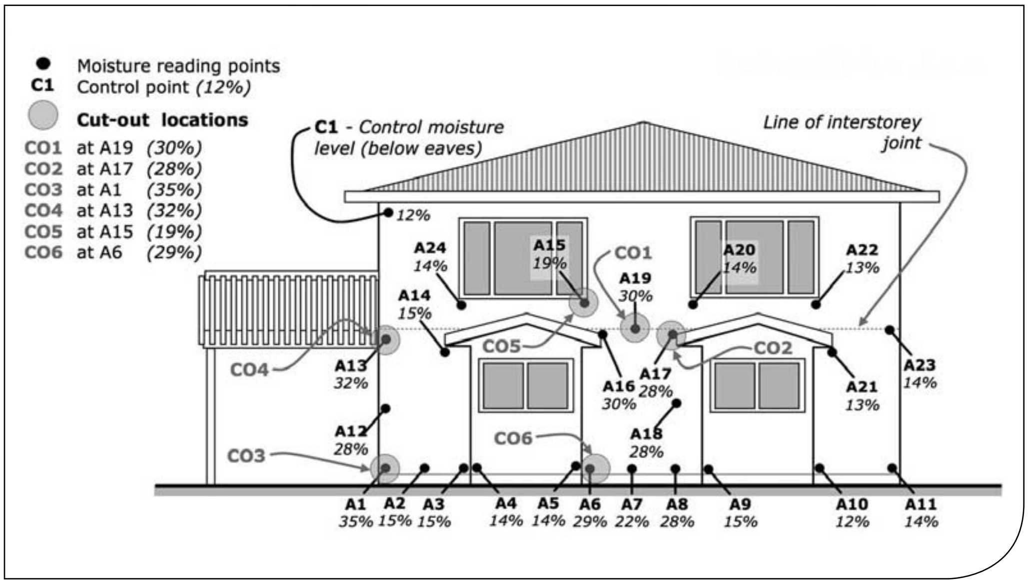
- Area 2 (the left-hand corner) – refer to A1, A13, etc
  Initially, it appears that water has penetrated the cladding from the adjacent deck where the deck fixings are unsealed. The deck/wall flashing is suspect as well as the balustrade junction. This moisture is most likely to have travelled to the corner.

  The resulting movement of timber and cladding has caused the deficient (non-draining) detail at the horizontal inter-storey joint to fail, causing further cracking and moisture penetration.

  Water has then flowed down through the corner framing to the bottom plate level, where moisture has been trapped due to a similar lack of drainage, causing damage to the framing at A1.

- Area 3 (bottom corner of upper, left-hand window) – refer to A15
  Although the moisture content is slightly above the 18 percent threshold (confirmed by taking further moisture content readings after the cut-out was made), only minor visible signs of moisture ingress and mould were found. The laboratory analysis reported the timber framing sample showed incipient decay that will probably continue without at least some in situ preservative treatment to avoid further decay.

Figure 6: Location of moisture readings



Step 6 – Developing the remediation recommendation

The evidence and analyses have been carefully weighed up in order to reach some firm conclusions. The recommendations set out below for the extent of cladding and timber framing replacement (with reference to Figure 5) consider both current and potential damage.

Current damage

It has been concluded that the area including A6, A7, A8, A16, A17 and A19 will require removal of the cladding and replacement of the framing. This is because the timber is untreated and decayed – a rule-of-thumb approach is that all timber one metre from the limit of any decayed timber should be removed and replaced.

Because the inter-storey joint has not been installed in accordance with the manufacturer's specifications and has failed at A19/CO1, sufficient cladding will have to be removed to install a complying joint. High readings at A16 and A17 indicate a problem around the apron flashings to the bay windows. The cut-out at CO2 confirmed that the flashing detailing was insufficient.

Cladding will need to be removed at the left-hand external corner at A1, A12 and A13 to allow the necessary timber replacement, and similarly horizontally one metre from the assessed edge of decay. On this elevation, the practical approach would be to take out the area of the wall along to the bay window. Removing the cladding around the full length of the faulty inter-storey junction will allow access to the first floor framing as the bottom plate and bottom part of the studs are likely to be affected (A19 has incipient decay). NZS 3604 does not allow joins in studs, so the framing needs to be properly exposed.

It is becoming increasingly unlikely that removing only isolated sections of cladding in this example will result in a successful remediation outcome. In addition, the framing at the corner on the adjacent elevation and around the decking and balustrade attachments will still have to be closely investigated when continuing the assessment of the whole building.

Potential damage

The implications for potential damage have been assessed.

First, A16 and A17 apron flashings show problems, but A14 (15 percent) and A21 (13 percent) indicated low moisture readings when inspected (after a three-week dry spell), despite their missing kickout detail. Although the additional water ingress from the incorrect inter-storey flashing (CO1) will need to be considered in relation to these faulty apron flashings, it is assumed that the potential for future failure at all these repeated apron flashing locations will be similarly high.

Secondly, the higher moisture content reading at location A15/CO5 (19 percent) was considered. It is assumed that the window installation conformed to the manufacturer's specifications at the time of construction. Even though a building detail or design may be built a different way today (for example, where an Acceptable Solution provides a different way of building that detail), this is not necessarily a defect that will result in future failure. However, the moisture content reading of 19 percent at A15 was more than 3–4 percent above other moisture contents, hence the cut-out at CO5.

Note: Where details that prove to be faulty on this elevation are similarly repeated on other elevations, it indicates the reasonable probability of future weathertightness problems in those other locations too. The investigation will need to establish further whether there are sound technical grounds to definitely rule out the probability of future failure, such as further invasive moisture testing and destructive cut-outs that show no moisture/decay, or otherwise existing mitigating factors (such as a different cladding system or sufficiently treated timber).

Summary recommendation – for this worked example of the one elevation

At least 60 percent of the framing on this elevation will need to be either replaced or otherwise treated in-situ with preservative. However, removing only parts of the cladding will not give clear access to the underlying untreated wall framing and defective flashings in this leaking elevation of the flush-finished, fibre-cement cladding system.

Rectifying the inter-storey joint in itself will effectively require much of the cladding to be removed from corner to corner. The decayed timber will need to be replaced when the left-hand corner is rebuilt, as will the wall between the bay windows plus any damage rectified to the first floor bottom plate, wall studs, boundary and floor joists. Any remaining timber will need to be treated in-situ, where appropriate according to the laboratory results, to reduce the risk of continuing decay. Furthermore, were the upper storey cladding to remain, some complex inter-storey flashing would still be necessary and the potential risk of window leaks on the upper storey would still need to be addressed.

For these reasons, the recommendation for this elevation is that all cladding should be removed to effect satisfactory repairs.

If the existing monolithic cladding system is to be replaced with another face-sealed monolithic cladding, then a cavity will be required under the weathertightness risk matrix of E2/AS1 to help drainage and drying of any moisture that penetrates the cladding.

The two bay window penetrations will require proper apron flashings and the ridge/wall junction will need to be installed properly.

This recommendation would then offer sufficient certainty that the remedial building work will meet the requirements of Building Code Clauses E2 (External Moisture), B2 (Durability) and B1 (Structure).

Finally, this example focuses on just the one elevation, whereas a full assessment would need to continue around the building. There is evidence of leaking and potential risk from the deck construction on the adjacent elevation (damp floor coverings around the door opening) that may already be contributing to leaks in the corner framing on this subject elevation.

APPENDIX V: FURTHER RESOURCES

The following is a list of various resources that can provide additional detail on many of the points raised in this guide.

Some of these publications may be out of date or superceded, however they can provide the particular construction details relevant at a certain period of time.

Department of Building and Housing – Publications are available from the Department as a free download from **www.dbh.govt.nz**, or freephone 0800 370 370.

Acceptable Solution E2/AS1
External moisture – a guide to using the risk matrix: June 2005
External moisture – an introduction to weathertightness design principles: August 2006
Constructing cavities for wall claddings: June 2006
Characteristics and defects – a study of weathertightness determinations: April 2007
External Moisture – a guide to weathertightness remediation: November 2007
Codewords 32: October 2008
Weathertightness Guide to Remediation Design: May 2011

New Zealand Standards – available from **www.standards.co.nz**,
or freephone 0800 782 632
NZS 3602 Timber and wood-based products for use in buildings
NZS 3640 Chemical preservation of round and sawn timber
NZS 3604 Timber-framed buildings

BRANZ publications – available from **www.branz.co.nz**
Good Stucco Practice: February 1996
Good Texture-Coated Fibre-Cement Practice: April 2001
Good Practice Guide Stucco: January 2004
Good Practice Guide Membrane Roofing: November 1999
Timber Cladding Good Practice Guide
Profiled Metal Wall Cladding Good Practice Guide
Weathertight Solutions, Volume One Weatherboards
Weathertight Solutions, Volume Two Stucco
Weathertight Solutions, Volume Three Profiled Metal
Weathertight Solutions, Volume Four Masonry
Weathertight Solutions, Volume Five Roofing
Weathertight Solutions, Volume Six Membrane Roofing
Maintaining Your Home, 2nd edition: 2006
Weathertightness Guide to Remediation Design: May 2011

BRANZ Bulletins – available from **www.branz.co.nz**
304: Flashing design: February 1993 (now withdrawn)
353: Ground clearances: February 1997
428: Weathertightness dos and don'ts: July 2002
434: Results of weathertightness failure: February 2003
435: Weathertightness evaluation: February 2003

448: Domestic flashing installation: April 2004
449: Keeping water out – timber-framed walls: June 2004
452: Aluminium windows and E2/AS1: August 2004
465: Domestic flashing installation: September 2005
466: Timber-framed parapets, balustrades and columns: September 2005
467: Principles of flashing design: December 2005
470: Wall underlays: February 2006
481: Timber windows: February 2007
493: Timber treatment: December 2007
505: Acceptable plans and specifications: November 2008
527: Drained and vented cavities: October 2010

Canada Mortgage and Housing Corporation
Building envelope rehabilitation – Consultant's guide: 2001
Building envelope rehabilitation – Owner-property manager guide: 2001

Occupational Health and Safety – available from www.osh.dol.govt.nz
Risks to health from mould and other fungi – Workplace Health Bulletin No. 17: 2002
WHRS Pamphlet on Moulds and Other Fungi: WD018

New Zealand Metal Roofing Manufacturers Inc.
– available from www.metalroofing.org.nz
Profiled Metal Roofing Design and Installation Handbook: 1995
New Zealand Metal Roof and Wall Cladding Code of Practice: v1 2003 and *v2 2008*

New Zealand Membrane Group. – available from www.membrane.org.nz
Code of Practice for Torch-on Membrane Systems for Roofs and Deck: 2008

Building Research Establishment – available from www.bre.co.uk
Recognising wood rot and insect damage in buildings, 3rd edition: 2003

Scion – available from www.scionresearch.com
Measuring the Moisture Content of Wood: Bulletin (Ian Simpson)

APPENDIX VI: GLOSSARY

The following provides a brief explanation of the meanings of the terms used in this guidance document.

Acceptable Solutions	Examples of materials, components and construction methods published by the Department that, if used, will comply with the Building Code. They are one way, but not a mandatory way, of complying with the Code.
Acceptable Solution E2/AS1	An Acceptable Solution for Building Code Clause E2 External Moisture
Assessor	The person undertaking the diagnosis stage of remediation. May also be known as the building surveyor.
Building	The building may also be known as a private residence or dwellinghouse. The fundamentals of the diagnosis guidance may be applied to some low to medium-rise non-residential buildings.
Building consent authority (BCA)	A BCA can be an organisation, such as a territorial authority or a private body, that is accredited to carry out certain building control functions as defined in the Building Act 2004.
Control point	A location known to be dry and undamaged (such as below the eaves) that is set up as a reference point, against which moisture content measurements from other locations may be compared.
Cut-out	The removal of a small section of cladding to allow inspection of the underlying construction (including moisture and decay testing of samples of framing timber if appropriate).
Decay	Deterioration of timber due to the action of fungi that become established within building timbers when moisture levels are elevated above fibre saturation in untreated timber.
Defect or deficiency	An aspect of a building's design, construction or alteration, or of materials used in its construction or alteration, that has enabled or is likely in future to enable water to penetrate it and cause damage.
Department	The Department of Building and Housing.
Destructive	Testing or sampling that involves removal of sections of cladding to examine underlying construction or to extract samples for laboratory analysis.
Direct-fixed cladding	A cladding that is fixed directly over the building underlay to the exterior wall framing (that is, without a drained cavity).
Drained cavity	Cavity behind a wall cladding – as defined in E2/AS1 (refer to Acceptable Solution E2/AS1 – 3rd edition).
Drillings	The swarf (timber debris) removed when drilling into the framing in order to take invasive moisture readings.

Equilibrium moisture content (emc)	The moisture content at a control point or reference point deliberately chosen to represent the 'dry' area of a building with timber framing unaffected by moisture ingress. The reference point will typically be under the eaves or some other suitably protected area.
Invasive testing	Testing that involves drilling into the wall to measure the moisture content within the framing (in contrast to non-invasive testing that uses surface measurement).
Iterative process	The process of revisiting, adding to and reassessing earlier work – based on increasing knowledge developed during the process.
LOSP	Light Organic Solvent Preservative – used in timber treatment.
Monolithic claddings	Wall cladding systems that are flush-finished or otherwise face-sealed to simulate plastered masonry and rely on protective coatings for weatherproofing (for example: flush-finished fibre-cement sheet, stucco or EIFS).
Moulds and fungi	Decay fungi can cause rot and decay in timber. Moulds are fungi in the form of simple microscopic organisms that release spores that can be inhaled. Mould and sometimes sapstain (or blue stain) fungi can be found on many building materials in the presence of high humidity, but are usually present where any material containing cellulose (timber, fibre-cement, Kraft-based building paper or plasterboard) is wetted.
Owner	The building owner, in this guide, may also be a party or 'claimant' to a dispute or otherwise some litigation process.
Remediation	The investigative, design and associated construction processes required to repair a building that has deficiencies causing (or likely to cause) moisture penetration and consequential damage to make it adequately weathertight and durable.
Risk matrix	A table from Acceptable Solution E2/AS1, used to simply calculate the representative level of weathertightness risk applying to a building design.
Samples or sampling	Materials removed from a building (such as timber, building underlay, linings, carpet) that will be sent away for laboratory testing.
Stachybotrys atra	A toxigenic mould that has been implicated in health risks for some people who come into contact with it. Refer also to Moulds and fungi.
Territorial authority (TA)	City or district council responsible for community wellbeing and development, environmental health and safety (including building control), infrastructure, recreation and culture, and resource management.
Weathertight Homes Resolution Service (WHRS)	A service established through the Weathertight Homes Resolution Services Act 2006 to help owners of buildings who have suffered damage to their properties due to water ingress.

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