Running a Museum:
A Practical Handbook

PUBLISHER:
ICOM – International Council of Museums
Maison de l'UNESCO
1, rue Miollis
75732 Paris Cedex 15
France

ICOM is very grateful to the United Nations Development Group Trust Fund (UNDG TF) for making this publication possible.

Editor and Coordinator: Patrick J. Boylan
ICOM Secretariat Coordination: Jennifer Thévenot
Layout and cover design: Edward Moody Design
Printer: Franly S.A.

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Also published in an Arabic language edition,
ISBN 92-9012-658-2

ISBN 92-9012-157-2

Hazards — risk

Care and Preservation of Collections

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Introduction to collection preservation

Conservation and preservation literature can often seem to be dominated by huge (and ultimately unachievable) lists of things to do. One can become so busy following parts of this good advice that there is never time to stand back to see if this really is the best way to achieve the fundamental objective of preserving the collection. This chapter therefore adopts a recently developed way of viewing the preservation and conservation of collections as a whole, before focusing in on the details.

At the same time, collection preservation remains an intensely practical business in which detailed practical advice is needed alongside this new way of thinking. Therefore this chapter also contains many practical examples and case studies (based on real events or an amalgam of real cases) drawing on the author's experience in surveying and advising museums, large and small, in many countries, including Egypt and Kuwait. It is not possible to cover all details of care and conservation standards and procedures in such a short introductory chapter, so where useful references exist these are noted.

Deciding priorities and assessing risks

Fundamentally, all heritage preservation, including that relating to museum collections, relies on two stages of decision-making:

1. Selection: what can and should be preserved within the resources available to the museum?
2. Assessing and managing risks: using human and other resources to reduce future damage.

The selection phase is mainly the concern of other chapters of this book, (particularly those on The Role of Museums and the Professional Code of Ethics, and Collections Management). However, it is important to understand that the nature, choice and history of the collections largely determines how much energy and resources the museum needs for preserving its collections.

In both small and large museums, most of the collection arrived long before the current staff. Decisions on acquiring new objects are often disconnected from those who understand special preservation requirements, though increasingly museum acquisition policies call for a condition and conservation assessment before purchasing additional items or accepting donations. As the removal of objects from the collections (deaccessioning) is rare, and often painful, in most cases the museum collections are always growing. They are also always aging.

These facts create two of the fundamental problems of collection preservation. There is constant pressure on storage leading to less than ideal storage and study space and therefore overcrowding. At the same time, the conservation needs of many categories of artefacts increase markedly with the age of the collection. Many items, such as archaeological metals or historic machinery, can deteriorate more rapidly once they have been "saved" by a museum than when they were sealed in the ground or in use in the historic factory.

Although museums tend to assume that the only way to address the imbalance between the needs of the collection and available resources is to search for new staff, space and money, the museum and its community must, from time to time, pose three questions: Why preserve these particular things? What new things do we want to collect? Why? (See also the Collections Management chapter.)

Reducing future loss and damage in 100 years or more

In both its everyday use, and as a technical term, risk simply means "the possibility of loss." In the past, museums used the word risk only for the possibility of rare and catastrophic losses, such as fire, theft, war damage, or major natural disasters. In this chapter, "possibility of loss" includes equally the gradual and cumulative damage to collections caused by agents such as damp, insects, light, and pollution. Preservation of collections is the reduction of all and any future losses. It is risk management of the collections.

The terms risk and risk management are widely used now by other fields, including other museum subjects besides preservation of the collections. The chapter on Museum Security provides information on risk management in relation to the overall risks to the museum and its buildings. The Managing People chapter provides information on health and safety risks in relation to staff and visitors. In all applications the basic concept remains the same, reduction of the possibility of loss.

Risk management of collections is not about the next year, or the next ten years, or even our own lifetime. It is about our children's lifetime, and that of their children, and so on. Experience in risk management of collections has shown that a practical benchmark for thinking about risks is 100 years. The important skill in risk assessment is to be able to find all the different reasons why, in 100 years, your collection will be in poorer condition than it is now, and to describe each of those many reasons in ordinary words. Later sections will suggest how to do this systematically.

Classifying risks to collections

There are many different ways to classify and list the potential causes of loss and damage to collections. When trying to understand and plan preservation, however, it does help to choose a single viewpoint of these causes and then to apply it consistently. It is also important that the list of causes be complete, so that in our work of preserving the collections, we do not forget something.

This chapter uses the object viewpoint of causes, developed by the Canadian Conservation Institute (CCI), and originally promoted in the information poster A Preservation Framework, (available both in hardcopy and on the Web at www.cci-icc.gc.ca). For example, causes of breakage may be staff untrained in safe handling of artefacts, or an earthquake, but in both cases, the cause at the object itself, the agent that acts directly on the artefact, is a direct physical force. There are Nine Agents of Deterioration that cause damage or loss to collections. These are 1 direct physical forces, 2 thieves, vandals, and displacers, 3 fire, 4 water, 5 pests, 6 contaminants, 7 radiation 8 incorrect temperature, 9 incorrect relative humidity. These agents are listed in more detail in Table 1.

The value of this classification is that it helps focus thinking about collection risk management. For example, physical forces (an agent of deterioration) acting on a ceramic object, or an entire collection, may cause deformation, or fracture, or surface loss (risks). The risks are basically the same whether the physical force is caused by an earthquake throwing objects to the floor (a hazard), or caused by a curator moving overcrowded objects during the preparations for an exhibition (another hazard). However, if the artefact is held firmly by a padded support, then it is protected from all such hazards. In other words, the padded support reduces the risk from physical forces, which may have many causes in a chain of causes. In another example, thieves, vandals, and displacers (a person who moves the artefact to a wrong location) all act on the artefact in a similar way: they pick it up and take it somewhere unknown. The hazards, the ultimate causes, may therefore range from local criminals to absent-minded researchers, but as far as risk management procedures are concerned, the benefits of controlled access, and frequent inventory inspection using good documentation, will be the same.

Table 1 links the agents to their risks and hazards. The distinction between risk and hazard are defined technically by experts from the larger field of risk management (see the glossary at www.sra.org) but the ordinary dictionary definitions contain the essence: Risk means "possibility of loss", hazard means "source of danger". (The interesting origin of the English word hazard is the Arabic word az-zahr, meaning the dice used in a game of chance. Danger and chance have always been linked in human affairs.) Whereas a list of all possible hazards is indefinite, as is a list of all possible risks, the list of Nine Agents of Deterioration is, mercifully, complete.

As an example of all the terms (agent, hazard, risk) consider the risk of colour fading in a textile on display. The agent of deterioration is the light reaching the artefact surface. The intensity of this agent can be measured by a simple and relatively inexpensive light meter. (The units of light intensity are lux – lumens per square metre). The hazard in this case could be an inappropriate lighting system, or an exhibit designer who designs to the wrong intensity, or a preparator who placed the textile very close to the lamps, or the maintenance technician who used the wrong replacement lamps, or the daylight falling on the textile from an unprotected (or inadequately protected) window, or the architect who designed the skylights, or the guard who contrary to instructions opens the special curtains intended to control the light in the room.

Preservation of collections involves all museum staff

Table 1 also shows the links to other museum activities and disciplines involved in the control of particular risks. Many activities and specialists in the museum are involved, directly or indirectly, in collection preservation. Curatorial, collections management, documentation, exhibition, security and management staff all have major contributions to make.

Teamwork and shared responsibility are now widely recognised as essential elements of modern museum management and operation, and this applies especially to achieving effective preservation of collections. This is not just a theoretical issue: it is essential in ensuring that the museum's limited resources are used effectively. In the author's experience, small museums practice teamwork and shared responsibility naturally. They are better able to see the whole picture, better able to incorporate new preservation advice, and better able to coordinate layers of preservation than staff in large museums. In large museums, hierarchy, specialization, and competitiveness often displace teamwork and shared responsibility. In such situations, a shared vision of preservation, alongside other museum functions, will only emerge if this is part of the enthusiastic leadership of senior management.

The collection preservation cycle

Preservation of collections is an endless process. Activities can be generalised as a cycle that repeats, shown in figure 1 on page 57. Each of these stages in the cycle will be explained later in this chapter.

Table 1. The Nine Agents of Deterioration

Agent of Deterioration	Risks of the Agent (Form of loss or damage, and the vulnerable collections)	Hazards (Sources and Attractants of the Agent) Partial list	Some other activities and disciplines involved in management of each risk
Direct physical forces e.g., shock, vibration, abrasion, and gravity	Breakage, distortion, puncture, dents, scratches, abrasion. All artefacts.	Earthquakes. War. Poor handling. Overcrowded storage. Transit inside and outside the museum.	Conservation.* All museum staff for detection, handling, and for emergency response. Building cleaning services. Emergency preparedness, museum and government.
Thieves, vandals, displacers i.e. unauthorized human access and removal. 1 Intentional 2 Unintentional	1 Total loss, unless recovered. All artefacts, but especially valuable, and portable artefacts. Disfigurement, especially of popular or symbolic artefacts. 2 Loss or misplacement. All artefacts.	Professional and amateur criminals. General public. Museum staff. Highly visible precious artefacts.	Security. Collection management. Curators and researchers. Local police.
Fire	Total destruction with no recovery. Scorching. Smoke damage. Collateral water damage. All artefacts.	Exhibition installation. Faulty electrical, lighting systems. Arson. Careless smoking. Adjacent buildings.	Security (fire). All museum staff for detection. Local fire service. Conservation*
Water	Efflorescence or tide marks in porous materials. Swelling of organic materials. Corrosion of metals. Dissolution of glue. Delamination, tenting, buckling of artefacts with layered components. Loosening, fracture, corrosion of artefacts with joined components. Shrinkage of tightly woven textiles or canvases.	Floods. Storms. Faulty roofs. Internal faulty water and sewage connections. External faulty water and sewage connections. Wet pipe fire suppression systems.	Conservation.* Emergency preparedness, museum and government. All museum staff for detection, and for emergency response. Building cleaning services.
Pests 1 Insects 2 Vermin, birds, other animals 3 Mould, bacteria (see Incorrect Relative Humidity: damp)	1 Consumption, perforation, cuts, tunnels. Excreta that destroys, weakens, disfigures, or etches materials, especially furs, feathers, skins, insect collections, textiles, paper, and wood. 2 Consumption of organic materials, displacement of smaller items. Fouling with faeces and urine. Perforation, fouling of inorganic materials if they present an obstacle to reaching the organic material.	Surrounding landscape. Vegetation habitats near building perimeter. Garbage habitats. Incoming building materials. Incoming artefacts. Incoming staff, visitors. Spilled foods.	Conservation.* Building operations. Food services. Exhibit design. All museum staff. External pest control companies. External biologists for identification.

Table 1. The Nine Agents of Deterioration – continued

Agent of Deterioration	Risks of the Agent (Form of loss or damage, and the vulnerable collections)	Hazards (Sources and Attractants of the Agent) Partial list	Some other activities and disciplines involved in management of each risk
Contaminants 1 Gases, Indoor and outdoor gases (e.g., pollution, oxygen) / 2 Liquids (e.g., plasticizer, grease) / 3 Solids (e.g., dust, salt):	Disintegration, discolouration, or corrosion of all artefacts, especially reactive or porous materials.	Urban pollution. Natural pollution. Building materials. Packaging materials. Some artefacts. Cleaning materials.	Conservation.* Building operations. Exhibit design. Building cleaning services.
Radiation 1 Ultraviolet light 2 Light (Visible radiation)	1. Disintegration, fading or darkening or yellowing of the outer layer of organic materials and some coloured inorganic materials. 2. Fading or darkening of the outer opaque layer of paints and wood to a typical depth of 10 µm to 100 µm, or to greater depths on more transparent layers.	Daylight. Skylights, windows. Electric lighting.	Conservation.* Architects. Building operations. Exhibit design. Security staff.
Incorrect temperature 1 Too high 2 Too low 3 Fluctuations	1 Gradual disintegration or discolouration of organic materials, especially if they are chemically unstable (e.g., acidic paper, colour photographs, nitrate and acetate films). 2 Embrittlement, which results in fractures of paints and of other polymers. 3 Fractures and delamination in brittle, solid materials, especially if they are layered. Cause of RH fluctuations (see "Incorrect Relative Humidity").	Local climate. Sunlight. Faulty mechanical systems	Conservation.* Architects. Building operations. Exhibit design.
Incorrect Relative Humidity 1 Damp (over 75%rh) 2 Rh above or below a critical value 3 Rh above 0% 4 Rh fluctuations	1 Mould (which stains and weakens organic and inorganic materials), corrosion (of metals), and shrinkage (of tightly woven textiles). 2 Hydrates/dehydrates some minerals and corrodes metals that contain salts. 3 Gradually disintegrates and discolours organic materials, especially materials that are chemically unstable (e.g., acidic paper). 4 Shrinks and swells unconstrained organic materials. Crushes or fractures constrained organic materials. Causes layered organic materials to delaminate, tent, and/or buckle. Loosens joints in organic components.	Local climate. Water leaks. Cold walls. Faulty mechanical systems. Inadequate ventilation.	Conservation.* Architects. Building operations. Exhibit design.

A case history of museum teamwork: sunlight and guards

A curator acquires an old textile from a local family. She has wanted it for the museum collection for many years. The textile was kept in the great-grandmothers dowry chest. They have agreed to give it to the museum if it goes on display in a prominent place. She studies the wall where she wants to mount it, and notices that at this time of day a bright beam of sunlight falls on the wall. The window shutters had been opened by the cleaners, and kept open by the security guard because they want ventilation. The curator asks about closing the shutters but they complain that it will be uncomfortable while they work. She has read somewhere that light can be damaging to textiles, but she is not sure.

Her museum is too small to have a specialist so she contacts an expert at the national conservation institute. After correspondence, he advises her that indeed, some of the colours in the textile she describes will probably fade significantly in two years if they receive two hours of direct sunlight each day, and even the indirect daylight in the room will probably cause fading in ten years. She decides to focus first on the biggest risk, the direct sunlight. She arranges a meeting with the cleaner and the guard in her office. She invites them to inspect the wonderful textile, explains its historic connection to the community, and explains the dilemma. After some discussion, the guard suggests that now that he understands the reasons, he could close the shutters for the two hours that the sun is a problem. He could move his seat to another open window without sun during that part of the day.

During the discussion the cleaner remarks that last year, when it rained, (when the curator was on holiday) she discovered dirty water on that wall from a roof leak, but she cleaned it up. She said she did not know who to tell. Perhaps that might also be a problem? The curator realizes she must speak now to the display case maker, and the man responsible for the building roof, to solve the water risk. The cleaner and the guard feel more attached to the museum collection, and understand that they too have a recognized role to play. They are, after all, the staff who look most closely at the exhibit room every day, and their observations form a valuable part of collection monitoring.

Exercise: Recall any teamwork experiences, positive or negative, or, if it has never happened, imagine where and when in your museum you could be involved in sharing such knowledge. Draw on a sheet of paper circles representing at least 3 or more individuals in your museum and show by arrows connecting the circles what knowledge or activity is shared. If there are organisational barriers between individuals, draw heavy lines between the two, that block the arrows. Does your museum look connected?

Some specific things, such as building a better storage room, can provide benefits long after they are completed. Other things, such as monitoring the room for insects, must continue indefinitely (with its own cycle).

More subtly, the planning and design of the new room, and the decision to allocate time and resources to the insect monitoring, must themselves be part of the general cycle of preservation.

Who takes the preservation leadership roles?

Traditionally, museums have fragmented the preservation cycle, especially larger museums. Much of the reorganization of museums in the last 20 years has

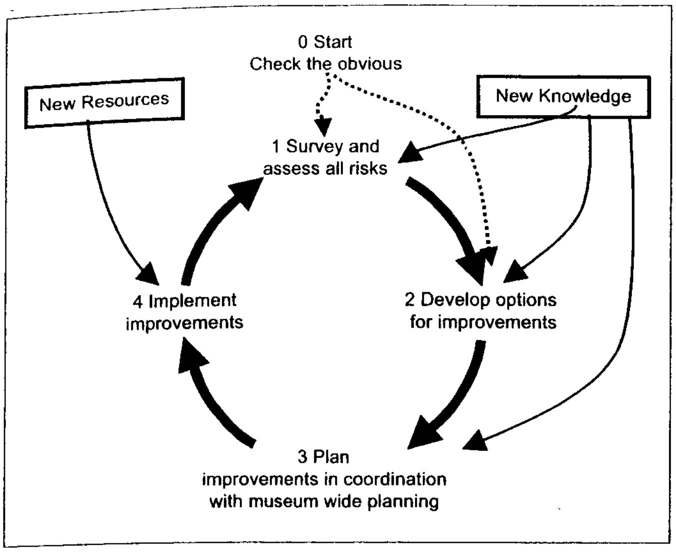

Figure 1. The collection preservation cycle, that must be coordinated within other museum planning cycles.

centralised collections preservation responsibilities under a Collections Management Department or unit. Within it, there may or may not be Conservation Department. The Security Department is usually separate from the Collections Management unit, while planning often takes place in each Department separately, with only the Director's Office able to coordinate policy and decision-making. However, in a very small museum, these are all just different roles that one or two people share.

In a large museum with a separate Conservation Department, the chief conservator typically takes the lead in the condition survey and collection risk survey of the collections, and in developing possible options. Alternatively, it may be the collections manager who leads the assessment cycle, while small museums often hire in on contract a conservator with experience in surveying. In some countries the cost might be paid through a government grant, while some countries have permanent government-funded agencies that will undertake surveys and give advice. In any of these cases the surveyor or surveyors writes a report that describes the risks, and usually makes recommendations for improvements. The report then becomes part of the museum's planning documents.

Regardless of who takes the lead in performing the survey and in planning the preservation cycle, the Director must take a key role, as this will contribute to the overall museum planning process.

Other types of conservation survey

There are several other possible forms of survey in addition to the model emphasized in this chapter, with a range of names, for example preventive conservation surveys, conservation surveys, or collection surveys.

Some organizations have developed special survey forms that allow standardized information to be collected across many museums in a region. The answers form a description of the museums preservation activities and their facilities, but provide no analysis of what it all means to collection preservation. They usually rely on an expert to perform the survey, and they always rely on an expert to interpret the answers. Organizations have recognized this problem, and developed surveys that suggest guidelines for "good practice. Thus, the museum can compare their own situation with the national or local "best practice" in relation to preservation.

A more traditional type of conservation survey is the collection survey. Some of these have been automated in software. The purpose of such surveys is an assessment of the degree of damage of each artefact, or of the average artefact. Information may also be collected on an estimate of restoration work necessary for each damaged artefact, and even on such work previously executed.

All these issues of different surveys, and their role in museum life, are described well and in detail in Susan Keene's excellent book, (Keene, 2002) The author's own organization, the Canadian Conservation Institute, is working on a computer based system that will contain many detailed questions, with an encyclopaedia of expert risk assessments of the many possible answers, but such a tool is still in the future.

Where is conservation and restoration in all this?

One hundred years ago, the only job of those responsible for the care of museum artefacts was restoration, i.e., the repair and reconstruction of precious objects, one at a time. In the last fifty years, this profession transformed to that of "conservator/restorer." Conservation emphasizes treatments that clean, stabilise, and strengthen the artefact. Conservators will also sometimes restore, reconstruct old damage, but without attempting to deceive the viewer. It is still, however, treatment of one artefact at a time.

Conservators recognised the need to prevent new damage, and discovered that prevention methods could be applied across whole collections. This is called "preventive conservation" as compared to treatments that are now called "remedial conservation." The approach described in this chapter, risk management, expands the preventive conservation idea by insisting on a method that compares the effectiveness of each major category or item of preservation expenditure, current or planned.

Conservation, even restoration, of some special artefacts, is still necessary in museums, especially for works of fine or applied arts, archaeological materials, or historic materials that the museum wants to display. For large museums, there may well be a Conservation Department which performs all these functions, and which can also take the lead responsibility for the preservation ideas in this chapter. In small and medium size museums, conservation is available only by contract of an independent specialist, or in many countries, by a state sponsored conservation facility.

For a detailed definition of the conservator/restorer by the international organization that represents them, see the ICOM Conservation Committee web page, www.icom-cc.org. This also lists news of all its conferences, working groups and publications. The other international agency that all those working in preservation of collections should know is ICCROM, www.iccrom.org , an intergovernmental organisation established in Rome in 1959. It is the only institution of its kind with a worldwide mandate to promote the conservation of all types of cultural heritage, both movable and immovable. It aims at improving the quality of conservation practice by providing information, advice, and training, and by raising awareness about the importance of preserving cultural heritage, particularly though not exclusively in its more than 100 Member States.

Step 1: Check the basics

A list of the basics

There is a famous management maxim called Pareto's Law that says that most of an organisation's benefits (80%) are achieved by a small fraction (20%) of the organisation's efforts. In giving advice to museums about preservation of collections over many years, one does indeed discover that most of the preservation is achieved by a short list of recommendations, which we can call "The basic preservation strategies" or just "The basics". So, before proceeding to the refinements of risk management, it is useful to check the basics first. These are given in the box titled "The basic preservation strategies". Generally, one does not expect a large museum to have missed any of the basics, but the list does apply frequently to smaller museums, or to large museums with no resources.

The basic collection preservation strategies

Basic strategies that address all or many agents at once

1 A reliable roof. Reliable against local precipitation, covering all organic artefacts (and preferably most inorganic artefacts.) While this is obvious to even people outside museums, it also applies to large objects, such as historic vehicles, or historic machines with paint. They cannot be expected to survive many years if exposed to sun and weather.

2 Reliable walls, windows and doors that block local weather, local pests, amateur thieves and vandals.

3 Reasonable order and cleanliness in storage and displays. The word "reasonable" is crucial. It does not mean spend most of your time on obsessive neatness, which provides very little benefit, and can even be counterproductive. It means keeping sufficient order that objects are not crushing each other, that inspection and surveys are easy, that objects are raised off the floor, and that object retrieval is easy. It means sufficiently clean that pests are not given habitats, that metals do not accumulate corrosive dust, and that porous and difficult to clean artefacts are not soiled.

4 An up-to-date catalogue of the collections, with location of artefacts, and photographs at least adequate for identification of the object if stolen, and preferably adequate for identification of new damage.

5 Inspection of collections on a regular basis, in storage and in exhibits. This becomes especially important in museums that have limited resources for other strategies of preservation. The time period between inspections should be no less than the time it takes insect pests to mature from eggs (approximately 3 weeks for the clothes moth). Inspect not only for new damage, new signs of risks, but also for thefts.

6 Bags, envelopes, or encapsulation used wherever necessary. Except where other rigid boxes are already provided, this includes all small and fragile objects, all objects easily damaged by water, all objects easily attacked by local pollution, all objects easily attacked by insects. These enclosures must be at least dust-proof, preferably airtight, waterproof, pest resistant. Transparent polyethylene or polyester is the most reliable, such as food quality bags (e.g. "Zip-Loc" TM). There is a large literature on details of these methods for textiles, archives, coins, etc.

7 Strong, inert backing boards for all delicate flat objects, to support, and to block many agents from behind. This includes manuscripts, paintings on canvas, paintings on paper and board, wall maps, stretched textiles, photographic prints, (both in storage and on display). For any that have front surfaces vulnerable to pollution or water or vandalism, provide protection by glass.

8 Staff and volunteers are committed to preservation, are informed and appropriately trained. Basic strategies that address a single agent that is a high risk to most or all of the collection.

9 Locks on all doors and windows. These should be at least as secure as an average local home, and preferably much better.

10 A detection system for thieves (human or electronic) that has a response time less than the time it takes an amateur to break the locks or windows. If not possible, the most valuable artefacts are stored in another, more secure location, when the museum is unoccupied.

11 An automatic fire suppression system, i.e., sprinklers (or other modern systems). This can be considered non-critical only if absolutely all building materials and all collections are non-flammable, e.g., ceramic collections in metal and glass cases in a masonry building with no wood joists.

12 All problems of sustained damp are addressed quickly. Damp is a rapid and aggressive agent, causing many risks, such as mould, corrosion, and gross distortion. Unlike fire, floods, and insects, it is so common it is often tolerated. The two usual sources of damp are small water leaks and condensation due to large changes in temperature drops (as at night). Move the collection away from the damp. Fix the water leak. Ventilate against condensation.

13 No intense light, no direct sunlight, no powerful electric light, on any coloured artefacts, unless one is sure the colour has zero sensitivity to light, e.g., fired ceramics, fired glass enamels.

Why are these so basic?
The basic items in the list can reduce many different risks at once, often at low cost, or they reduce a single catastrophic risk that could affect all the collections and perhaps the museum itself. In the case of the first two (roofs, walls etc.) they do both. Reliable roof and walls block all nine agents of deterioration, not always perfectly, but always to a large extent. This fact may seem so obvious as to be facile, but for many museums guaranteeing a "reliable roof" and "reliable walls" is not so easy. In recent years there have been many reports that some of the most famous international museums have suffered from extensive water leaks dangerous for the

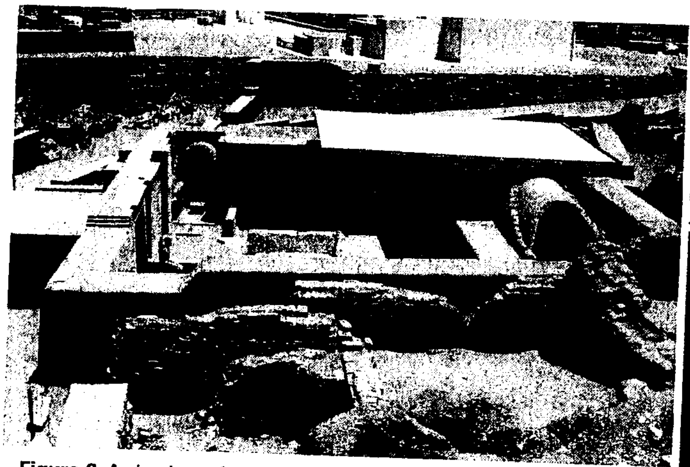

Figure 2. A simple roof structure built over a particularly important part of an archaeological site near a museum. Notice the subtle slope and gutter to direct rain away from the protected area, and avoid rising damp problems in the walls. A small price, a lot of effective preservation. All photographs in this chapter are by the author, Stefan Michalski, Canadian Conservation Institute, all except figures 9,10, made during teaching or consulting projects for UNESCO or ICOM, in or near Cairo, Aswan, and Kuwait City, between 1986 and 2002.

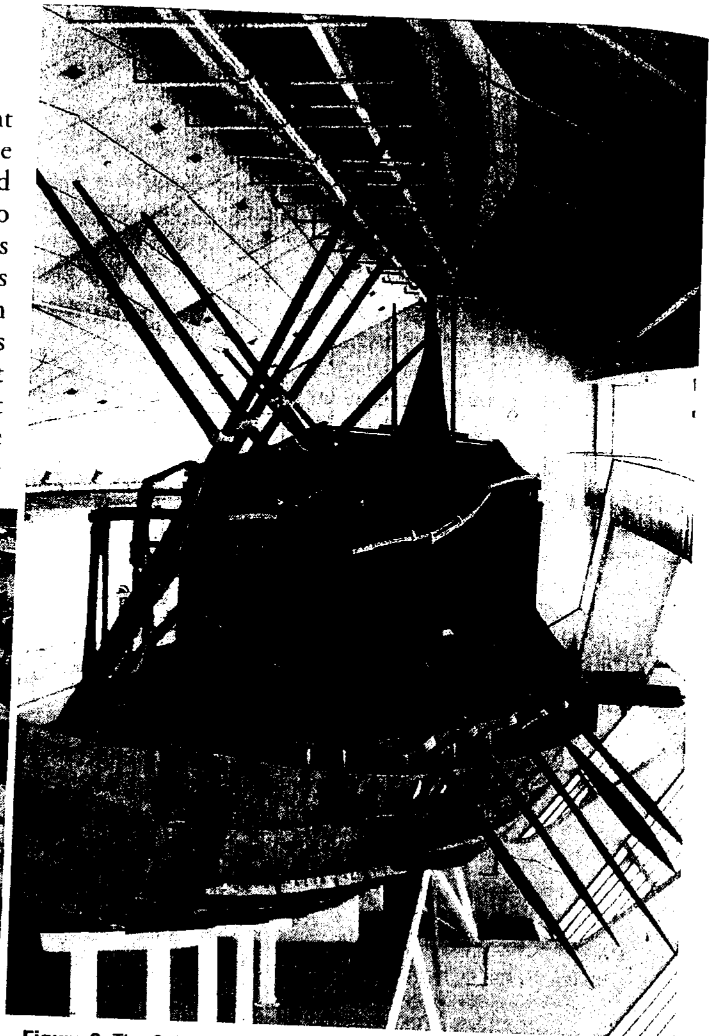

Figure 3. The Solar Boat in its own building, near the great pyramid. The need for sprinklers to control fire risk is obvious, but what are the risks from incorrect humidity and temperature for such an object? How can we know? What is the best way to achieve control reliably?

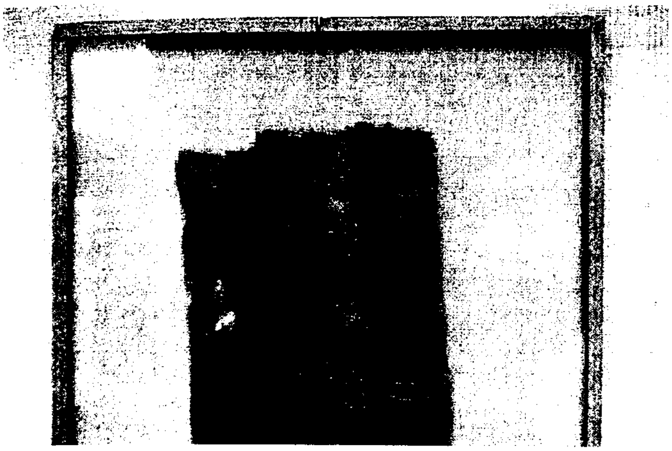

Figure 4. A papyrus manuscript on display in a small museum. Sandwiched between two layers of glass, and taped. A traditional and very cost-effective form of collection preservation. Provides a sealed enclosure that blocks water, pests, contaminants, and incorrect humidity. Provides protection from many, although not all, physical forces. Easily cleaned without harm to the artifact.

collections because of lack of proper maintenance or renewal. Besides, many large or immoveable artefacts are left outside. In figure 2, a simple roof is installed over the most important and vulnerable part of an archaeological site, nearby its associated museum. On the other hand, one can argue that perhaps the modern building around the solar boat (figure 3) with its extensive windows in the desert sun, does not reliably block the heat of local weather (unless the air-conditioning unit is functioning). At the opposite end of the scale very simple and inexpensive measures such as the use of suitable plastic bags, backing boards, or glass, can make a big difference to the protection of the collections, and will protect against most hazards other than burglary and fire. Figure 4, and a later example (figure 10), show these simple but highly effective methods in action.

Step 2: Survey the risks

When to start doing a survey, and how long will it take?

To identify risks to the collection, one can just react to situations as they arise, as did the curator in the case study on page 56. Or one can begin with the list of the basics, as in the previous section, and do that until it is finished. An alternative would be to begin immediately with a systematic survey, which will uncover the basics as well as the not so basic.

A simple survey of a small museum might take one experienced person three days, a detailed survey of a large museum may take several people several months. Whether the survey is a simple one, looking for high priority risks, or whether it is a detailed one looking for all risks, large and small, the guiding principle is "systematic and comprehensive". Too often in preservation of collections, staff have focused on old habits, on trendy new processes, on ad hoc reports, and on dealing with emergencies, real and bureaucratic.

In summary, a simple survey is better than no survey. Soon is better than never. The crucial aspect is to step back from your job, from your normal preservation activities, and look at your museum and its collections with open eyes, looking for anything that could possibly cause damage.

What exactly am I looking for?

The surveyor is looking for all possible risks to the collection. This is the most difficult part of risk assessment to explain, and of course, it is the most important part to make the survey useful. It is the part that benefits most from experience, but it is also the part that anyone can do. It needs common sense, reasonable intelligence, and good eyesight. It helps to have a feeling for the material world, to be what some might call a practical person, but it also helps to be imaginative, since one must imagine everything that might go wrong. It also helps to have a love for the collection, since that usually brings both a detailed familiarity and a strong concern for the collection's safety.

There are two stages to this search: collecting facts, and predicting risks.

Collecting facts in order to predict risk

The surveyor begins by collecting many facts, motivated entirely by the next step, which is to predict all the potential risks to the collections. The facts are best collected in a systematic pattern, and a suitable and proven model is outlined in the next sections. These facts must not contain any opinion or speculation, and it is necessary to agree where facts end and opinions begin.

The surveyor then predicts specific risks. Each specific risk is predicted by imagining a specific scenario of possible loss or damage, implied by each survey fact, or possibly implied by several linked facts. The key concept is that of imagining a possible loss, and then finding the best available facts to support a quantifiable prediction.

Fortunately, many serious risks can be imagined by common sense, and roughly estimated. Other risks, such as fading by light, is more a matter of scientific knowledge. For simple surveys, one does not need to be an expert to uncover most large risks. One needs only to be systematic.

Sources of facts: visible and invisible

A risk assessment survey relies on two sources of facts, and it reduces time and effort if one approaches each separately.

1. Visible facts. This is the part of the survey where we look with our own eyes, and make observations. One looks at the site, the building, the rooms, the furniture, and the collections.

2. Invisible facts. This is the part of the survey that considers prior history of the museum, current staff activities, procedures, attitudes, planning, as well as many external sources of data needed for risk estimation (e.g., flood data, earthquake data, light sensitivity data, etc.)

It is easier, though not essential, to keep these parts of the survey separate, simply because the visible part involves walking around the museum, inspecting things, taking notes, taking photographs, whereas the invisible part involves talking to staff and researching relevant documents. It is not critical which part is done first, but it is useful to have a general understanding of museum mandate, preservation policies, old planning documents, before surveying the museum. It is also very helpful to have copies of a floor plan for marking locations of observations.

Surveying visible facts

The collections can be considered as inside a sequence of containers, like boxes within boxes. Each adds its layer of protection. This is shown in figure 5.

The survey of visible facts follows a path from the outside to the inside. The surveyor begins by looking at the site, then at the building and all its features, then moves inside the building and looks at the building from the perspective of each room. For a pattern refined by the author over many surveys, see Appendix 1, "A suggested museum survey path, set of observations, and set of photographs."

Take pictures

Pictures capture many details. In the author's experience, photographs not only form powerful elements of a report, they form a practical record for the surveyor. One often notices things while staring at a photograph that one missed while in front of the real thing: did that room have fire sprinklers? Were all the manuscripts under glass, or only some? Were lights on in all cases? A photographic record also preserves facts for future comparative surveys.

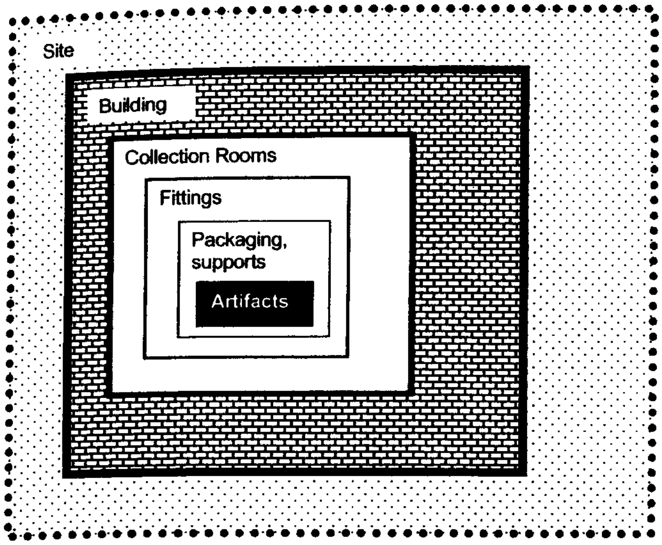

Figure 5. Nested layers around the collections.

In the past, making a hundred good photographs with film was relatively expensive, but with the advent of digital cameras of 3 megapixels or more, a surveyor can take many pictures at low cost and place them within reports or e-mails whenever necessary. It is especially useful to be able to check the quality of the photograph immediately, and to take it again if it is overexposed, out of focus, etc. Typically a survey of a small size museum will generate 100-200 photographs, a medium size museum 300-400. (A digital camera can make it easy for even a small museum to make its collections available over the Internet in due course).

Photographs should always be taken systematically according to a plan, not haphazardly. It is much easier when making use of the photographs later, especially in a museum with several rooms, to take them in a logical sequence. A suggested sequence for photographs is given in the Appendix "A suggested museum survey path, set of observations, and set of photographs". Also, in order to use photographs to record museum lighting, learn to make photographs of the building and rooms and display cases with the flash turned off. In low light, a tripod may be necessary.

Surveying invisible facts

Surveyors in the past sometimes stopped their survey after they had toured the building and the collections. This missed much of what determines collection preservation. A comprehensive risk assessment needs information from architectural drawings, from policy and planning documents, from manuals of lighting and exhibitions design, etc. It also needs facts that exist only in staff memory, even in museum habits, unrecorded but influential.

Do the staff always leave the back door open on hot days, even if the official policy forbids it? Do the lights in all display cases come on all night when the cleaners need to work? Has the roof or plumbing ever leaked? Where? Does the curator bring new artefacts into storage without quarantining them first, and without checking for insect infestations that could rapidly spread through the museum? Do staff eat food in the storage areas and thus attract both rodents and insect pests? Do staff smoke there? And so on.

Some important sources of information on risks will be found outside the museum. What are the local and regional hazards? Is the museum located on a flood plain or at risk from landslips? What is the probability of earthquakes? What is the frequency with which the identified natural hazards occur, and what is the current trend? (Changes such as the construction of new building developments or roads which obstruct the natural drainage can make a major and immediate difference to the risk of flooding.) To what extent are the collections sensitive to light and incorrect humidity levels?

A basic list in the Appendix gives typical sources and useful questions for invisible facts. Do not be limited by this list: it is only a starting point. You will always need to discover facts for your risk assessment that are not in this list, or any available list. One can rely on two guiding principles in this search: imagination, and prior history.

Imagination, means allowing yourself to imagine any specific risk that seems plausible. For example, you observe a Syrian glass lamp displayed with a bulb illuminated inside (figure 6). You imagine that perhaps the colours of the glass design will fade if the lamps are on all day. Someone told you yes, all colours are vulnerable to light, but someone else laughed and said, no, not coloured glass. Someone else, more careful, said authentic lamps with coloured glass are not a problem, but later lamps with coloured paint designs are a problem. So, given this plausible imagined risk, it immediately directs you to your requirements: You need to locate facts about Syrian lamps, different forms of coloured design, and the effects of light. Exercise: What do you think should be the lighting decision if there is no information available on the coloured design of a lamp?

Prior history of the occurrence of hazards in the museum provides extremely valuable facts. For example, the question "what are the risks from poor handling of artefacts throughout the museum" can lead you to a difficult theoretical analysis of handling by a complex system, or it can also direct you to ask a simple question of all staff: does anyone remember any stories of artefacts being dropped, scratched, or damaged in any way by handling, even five years ago, twenty years ago? Be sure to explain that the intent is not retribution, but solution. Names are not necessary, only the stories. You will discover that the collective memory of all museums contains stories of such minor events, never recorded before. Collect these: they are precious to understanding your collections preservation. Note that collecting prior history is a slow form of institutional "detect" (though ideally all such occurrences ought to have been properly investigated and recorded at the time). As with all

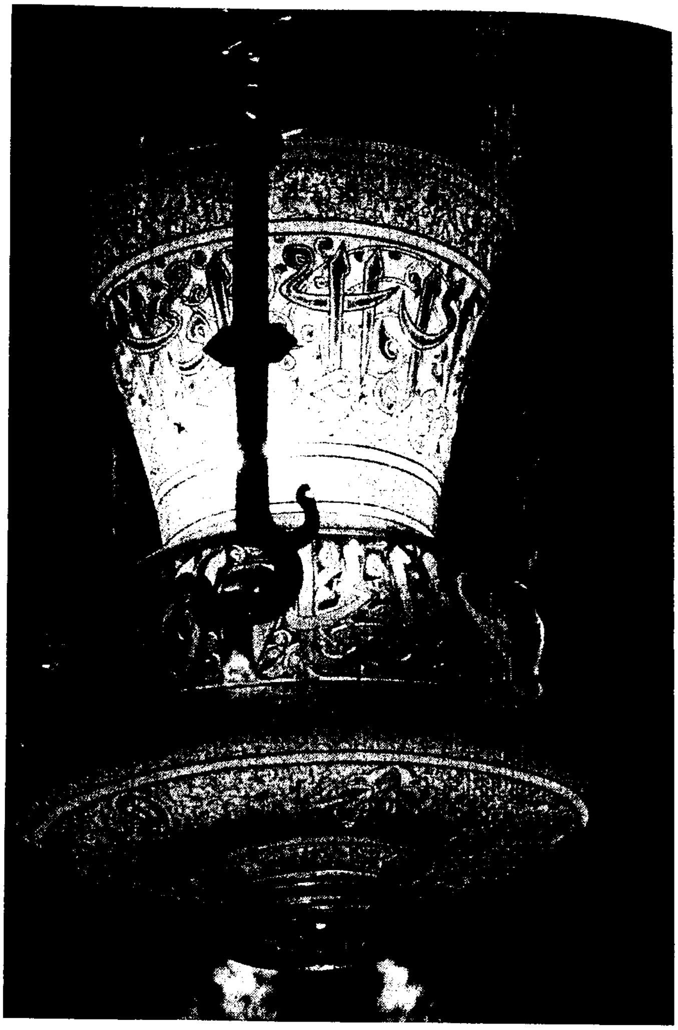

Figure 6. A glass lamp, with coloured decoration, exhibited and illuminated with an internal lamp.

detection, the purpose is to trigger a response that will lead to an improvement in the risk management in relation to the collections.

Assessing the collection risks, based on the facts

After collecting all the risks one imagines possible in a list, the question arises: which risks are more important, which risks less important? Traditionally, museums made such decisions by a mix of expert opinion (if available), personal opinion, and internal politics. Issues were often fragmented across various departments. These realities will still be part of practical museum decisions, but a survey report that assesses all risks to the collections provides a very useful starting point for discussions.

There are currently only two tested methods of comprehensive risk assessment for museum collections. One is a detailed, arithmetic method developed by Waller (2003) in a large national museum, and applied successfully to many medium and large-scale museums. The other is a method using simple rank order scales developed by the current author, applied successfully to a large number of small and medium size museums in Canada, and taught at several training courses, such as courses in 2003 and 2005 co-sponsored by ICCROM and CCI. Only the rank order approach will be presented here, but a good factual survey can always be converted later into an arithmetic assessment if desired. Rank order scales are common in risk management whenever non-experts do the assessment.

The scales in table 3 consider the following four components of the risk assessment:

How soon?
How much damage to each affected artefact?
How much of the collection is affected?
How important are the affected artefacts?

The magnitude of risk is then the sum of these four components.

The scores from each of the four scales are added together (NOT multiplied). This total score is the Magnitude of Risk due to the Specific Risk assessed. Overall, this simple system suggests the following categories of priority based on total score:

9-10: Extreme priority. Total collection loss is possible in a few years or less. These scores arise typically from very high fire or flood probabilities, earthquake, bombing, and fortunately, are rare.

6-8: Urgent priority. Significant damage or loss to a significant portion of the collection is possible in a few years. These scores typically arise from security problems, or very high rates of significant deterioration from bright light, UV, or damp.

4-5: Moderate priority. Moderate damage to some artefacts is possible in a few years, or significant damage or loss is possible after many decades. These scores are common in museums where preventive conservation has not been a priority.

1-3: Museum maintenance. Moderate damage or moderate risk of loss over many decades. These scores apply to the ongoing improvements even conscientious museums must make after addressing all of the higher risk issues.

Later in this chapter, there are worked examples of risk assessment using these scales.

It is not essential to use these scales in a risk assessment. A surveyor can choose simply to use terms like high, medium, and low, for risks, or "Needs to be done this year" versus "Can wait for ten years". What matters in the end is that the museum should be able to point towards some rational and understandable method in the survey for making some form of assessment, and that the entire museum and its diverse systems have been systematically surveyed.

Table 3. Simple scales for risk assesment

How soon? (rate, or probability, of damage)		
Score	**Risks that occur as distinct events**	**Risks that accumulate gradually**
3	Occurs about once every year	Damage occurs in about 1 year
2	Occurs about once in 10 years	Damage occurs in about 10 years
1	Occurs about once in 100 years	Damage occurs in about 100 years
0	Occurs about once in 1000 years	Damage occurs in about 1000 years

How much damage to each affected artefact? (proportional loss of value)		
3	Total or almost total loss of artefact	(100%)
2	Significant but limited damage to each artefact	(10%)
1	Moderate or reversible damage to each artefact	(1%)
0	Just observable damage to the artefact	(0.1%)

How much of the collection is affected? (fraction of collection at risk)		
3	All or most of the collection	(100%)
2	A large fraction of the collection	(10%)
1	A small fraction of the collection	(1%)
0	One artefact	(0.1% or less)

How important are the affected artefacts? (value of artefacts at risk)	
3	Much higher than average significance (100 times the average value)
2	Higher than average significance (10 times the average value)
1	Average significance for this collection
0	Lower than average value for this collection (1/10 the average value)

An example of the maximum possible score

How soon?	3
How much damage, to each affected artefact?	3
How much of the collection is affected?	3
How important are the affected artefacts?	1
Magnitude of Risk (total of above four scores)	10

Notes: It is not possible to score 11 points. If all the collection is at risk, then the importance of each artefact cannot be more than average, and if it is 10% of the collection, it cannot be more than 10 times average value.
Any of the scales can be scored intermediate half values if desired, e.g., 2.5

Step 3: Plan improvements to collection risk management

Five stages of collection risk reduction

All the very many, perhaps thousands, of ways that museums reduce collection risks can be subdivided into five stages: avoid, block, detect, respond, recover.

1. Avoid sources and attractants of the agent.
2. Block all access and paths for the agent (since sometimes step 1 fails).
3. Detect the agent in the museum (since sometimes steps 1 and 2 fail).
4. Respond to the agent after presuming, or detecting its presence (otherwise step 3 is pointless).
5. Recover from the agent's effects on the collections (conserve artefacts, and reconsider what went wrong and plan improvements).

The first four stages are prevention of damage. The last stage is remedial conservation and restoration, necessary only because the preventive stages failed. Of course, much of the damage in museum collections happened long ago, or before it entered the museum. Even the best collection care will not eliminate the need for remedial conservation.

Throughout the remainder of this section on planning improvements, remember that each of the five stages has a role to play, and that successful risk management balances all five. Later, when actually thinking about your own collection risk management, remember that each of the five stages is a powerful way to stimulate thinking about what might be missing in your museum.

Common-sense, good house-keeping, but there are complications

Many authors have noted that the strategies of traditional "good house-keeping" resemble good collection preservation. In other words, a lot of preservation is common sense. In fact, the "list of the basics" presented earlier would be very familiar to a housekeeper a hundred years ago. On the other hand, some habits of housekeeping can damage the museum collections.

For example, if nearby deserts, or dusty roads, deposit a layer of fine mineral powder on collections, then cleaning the artefacts regularly would seem like a good idea. Unfortunately, two problems arise: abrasion, and snagging.

Abrasion develops when the same dust-cloth is used over and over. Unless it is carefully cleaned every few minutes, the cloth fills with the abrasive dust, and the process of dusting becomes a process literally of sanding the artefacts. The author saw a collection of gilded furniture in Egypt stripped of almost all the gilding, simply because they were regularly "dusted" by cloth. A variation on the cloth problem occurs with feather dusters. The feathers wear quickly, and the spines of the feathers become sharp points that scratch the surfaces they dust. Painted surfaces in small historic house museums often show the multiple scratches of generations of feather dusters.

Snagging occurs with complex objects. It especially occurs with styles of furniture that use elaborate fretwork and inlays, common in Islamic decorative arts. The dust cloth or feather duster snags fragments that have curled or partially delaminated, and flings them somewhere far away! A museum cleaner questioned by the author (many years ago) about this issue angrily defended himself, and stated that his family had performed this function for generations. It was a mistake of diplomacy to raise the issue as a young, foreign expert, and in the presence of his supervisors. In retrospect, it is unlikely that anything changed about cleaning in that museum. Better to have informed the curator, who could later approach the staff member discretely.

A second complication seen repeatedly by the author in museums with a dust problem is water damage. The most common form of institutional floor cleaning, inside and outside, observed by the author in all the hot regions of the world East to West, appears to be mopping with copious amounts of water, often thrown in puddles on the floor, either early morning before the museum opens, or immediately after closing. Part of the reason is probably the pleasant cooling effect, part of the reason is the prevalence of tile floors and stone walls, with no wood components. Part may be the ritual of cleansing with water that occurs in many cultures where water is scarce. History and sociology aside, the very real risk as far as preservation is concerned, is the risk of water damage, as shown in figure 7. Here, in a major museum, no one in authority has noticed or acted on substantial change in the artefacts appearance, despite the obvious clues given by the plastic sheet protecting the eye. There is no damage under the plastic. And the nails holding the plastic are corroding very fast, and staining the wood even more. Obviously the protection of glass, such as figure 8, is better for a wood sarcophagus.

Find individual solutions, and then common solutions

For each risk identified and assessed (or at least for all risks selected as significant) a collection risk surveyor then develops a solution, or maybe several options for a solution. If possible, the surveyor estimates cost, or at least identifies the type and scale of resources required. In business terms, this then permits the museum to try a cost-effectiveness calculation: how much risk does each option control, and how much does this control cost? Individual examples are provided in the section on Examples of specific risk assessments and individual solutions.

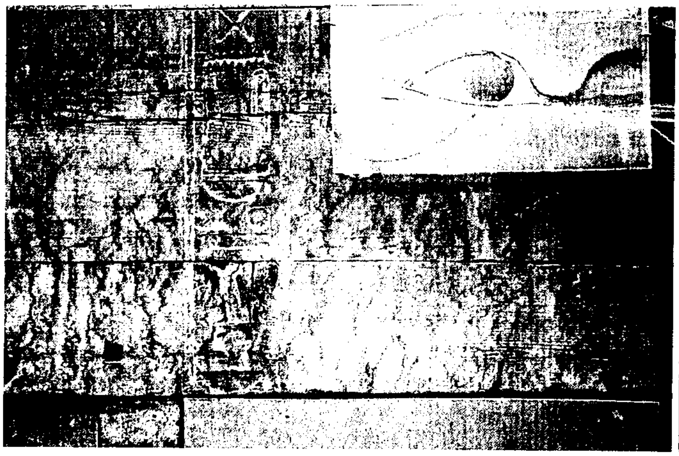

Figure 7. A wooden sarcophagus on open display, on the museum floor. The water stains are from many years of water splashed during daily floor cleaning with wet mops, a common procedure in hot dusty climates. The plastic protection over the eye reduced risk of vandalism, and also blocked the water splashes.

Figure 8. A sarcophagus in a modern museum case. While it is obvious that it blocks water from the floor cleaners, it is not obvious if it can or cannot block water leaks from above, or insects, or smoke, or pollutants. Close inspection, or design drawings, and probably both, are required for such assessments.

Recommending individual solutions works well if the survey has identified a few high level risks that have unrelated solutions. In such cases, simple business logic suggests that the museum should implement solutions to all high-level risks in order of increasing cost.

Finding common solutions to groups of risks is also possible, but may require exploration of different options, different solutions to each high-level risk. One then looks for options that address several risks at once. It may be more cost-effective to spend a little more on an option that solves several risks than to implement the lowest cost option of each risk.

The only planning dilemma arises when many small risks can be solved at low cost, whereas the one large risk can only be solved at high cost. Actually, this is not a dilemma so much as a risk management trap, or fallacy, that many museums have fallen into, and suffered as a result. Solving the low level risks that we can afford, or for which we have already assigned staff, makes us feel that we are truly doing our best to preserve the collection. And as noted at the beginning of this chapter, it is not difficult to fill one's time with habits that address low level risks.

Time after time, one sees museums that spend months of labour on special padding for textiles in storage, and do nothing to reduce the risk from the three water and sewage pipes that cross the ceiling of that same collection. Or museums that build beautiful wooden cabinets that solve small humidity risks instead of designing the cabinets and building to cope with the probable severe earthquake in a region of high seismic activity. Or museums that conserved paintings at great expense, which then dropped to the floor after installation because no one tested if the hooks were strong, and finally, the numerous museums that neglected to install sprinklers, or even decided not to install sprinklers because of perceived water risk, and burned to the ground. (It is interesting to note that old photographs of the solar boat museum (figure 3) on some tourist web sites show no sprinklers. Presumably they were added later, not in the original design.)

One last note on finding solutions: it is a common mistake to start thinking of risk management improvements only in terms of building something, or buying something. Many solutions to risks and hazards emerge in the intangible, such as staff training or improved communication. For example, one large museum discovered that over and over, there were preservation mistakes in new display cases (in lighting, supports, polluting materials.) The conservation department and the exhibitions department did not communicate regularly during exhibit design. Conservation was only obliged by museum policy to approve the exhibition at the final stages of installation. By then, it was too late, or too expensive, to make changes. The result was only animosity, and a dysfunctional relationship. The improvement was simple, with no cash cost: conservation was required to send a representative to exhibit design committee meetings, from start to finish. Later, conservation staff admitted that they had no idea that exhibit design was such a complex task, and that the lighting solutions they proposed, such as fibre optics, could be so expensive. (For an excellent resource on conservation issues and the exhibit design process, see the CD-ROM entitled Exhibit Conservation Guidelines: incorporating conservation into exhibit planning, design and fabrication, by the US National Parks. (Raphael, c 2000)

Find integrated preservation solutions

The word integrated has recently emerged as another preservation management ideal. It means to bring an independent and isolated activity into the larger system. The goal is not just a grand theory, but a practical holistic operation. It is a relative term, inasmuch as some apply it to the integration of pest control within the museum operations, others propose it for all preservation activities within the museum.

The challenge is this: An integrated method is a diffuse and system wide method that cuts across many independent museum activities. For example, integrated pest control requires, among other things, cleanliness under cabinets, plus reduced vegetation around the walls, plus mandatory quarantining of new artefacts, plus no food in curator's offices near storage, etc. Integrated relative humidity control requires that cabinet design and building mechanical systems and conservation monitoring form a complete and cost-effective system. Implementing an integrated approach depends on the cooperation of many museum staff and their departments. Sustained teamwork depends on shared understanding. Successful integrated solutions always begin with successful communication.

Find sustainable preservation solutions

Finally, the most modern concept in heritage preservation is "sustainable". A new university programme in sustainable heritage, for architects, engineers, and conservators, has just opened in the United Kingdom. (www.ucl.ac.uk/sustainableheritage) In essence, sustainable means the organization takes no more than it can give back. There are two flavours to its use in heritage preservation: environmental, and financial.

When thinkers in the conservation of the environment apply sustainability to heritage, it means that a historic museum building is a resource, and any plan to tear it down and replace it by a new building must consider that each brick thrown in the garbage, and replaced by a new brick, represents enormous "taking without giving" from the environment.

At a more day to day level, consider museum lighting. Fluorescent lamps are "low energy lamps" and by using them in museum lighting, one saves energy three times. First, one saves at the lamp, which consumes much less electricity for the same light as incandescent lamps (including quartz halogen lamps loved by exhibit designers.) Second, ones saves on the electricity to operate the air-conditioning that is needed when the museum is full of hot incandescent lamps (significant in many museums, especially in hot climates). Third, the size of the air-conditioning plant can be smaller, and hence the energy consumed by its manufacture and replacement is less.

Unfortunately, many compact fluorescent lamps contain a significant amount of complex electronics, and this becomes garbage when the lamp is replaced. Newer models of compact fluorescent lamps separate the electronics from the lamp (as do all large fluorescent lamps). Still, as any lighting designer will attest, using fluorescent lamps successfully in museum displays is not easy.

The other flavour of sustainability comes from the field of economics. Pragmatists here use the word simply to mean that the local finances of the museum will balance, not just this year, but indefinitely. The last two decades have seen many museums worldwide discover that they were not sustainable in these terms. Part of what drove their operating costs far beyond their resources was the installation of complex mechanical systems for temperature and humidity control. These expensive mechanical systems were driven by "conservation standards", which will be examined more sceptically in the section Museum temperature and humidity guidelines.

Plan within general museum planning, and beyond

The collection preservation cycle only has a meaning within an organisational structure that can implement it, such as your museum. Other chapters in this book deal with the planning and management of the museum as a whole. There will be times and places identified within that planning process for leaders of the preservation cycle to speak and plan within the larger museum planning cycle. The objective at museum planning meetings is not simply advocacy of preservation needs, but creative and imaginative collaboration. Listen to the other museum interests.

Recall the case history of the curator with a recent donation of a textile from an important local patron. Besides planning a good preservation (low risk) display, the museum may wish to consider the public relations aspect. Keep the donor happy, and other donors, and more gifts may appear. Also, the exhibitions and education departments may ask to present conservation and preservation aspects of the textile, such as how the museum treated the textile, how the textile was fabricated locally, what historic dyes might have been used, and thus full circle, why low lighting is necessary. Each of these possibilities are real, and each has occurred in successful museums.

Some readers of this chapter will become, or may be already, in positions of importance within national or even international heritage agencies. These agencies are being asked to demonstrate their results, and their cost-effectiveness. All are beginning to consider a preservation cycle of their own: assessment (where surveying intangible facts is called consultation with client groups), then option generation, then planning (coordination with client groups again), and only then, implementation. The next cycle of assessment then looks for results from implementation of the previous cycle, as well as new or unaddressed risks.

In fact, the author based the preservation cycle on a model taught by a lecturer on government program development, where the idea that the process was a continuing cycle, not a straight line with a start and a finish, was considered a breakthrough! Historically, though, the straight line project model, with a final ending, is understandable. New goals tend to have a short List of the Basics, which can be approached once, and completed. For old goals, however, like collection preservation in an established museum, improvements are not obvious, cost-effectiveness is far from obvious, and the results often uncertain. The cycle must be repeated, and new assessment data injected.

Figure 9. Islamic manuscripts on display in a small, modern museum. The cases appear well made, and the lighting appears of low intensity, with no lamps inside any cases. Examples of more precise collection risk assessments of this room are presented in the text.

Examples of specific risk assessments and individual solutions

Figure 9 . Islamic manuscripts (books in horizontal cases, single sheets in wall cases) in exhibit cases illuminated by electric lamps

A display room full of Islamic manuscripts, displayed as shown. Modern electric lamps. Modern, solid, display cases. Overall impression of collection preservation: excellent. Perhaps there are significant risks to the collection, or perhaps none. Only careful assessment can determine this.

Assessment of light fading risk in figure 9:

A measurement with a light meter is necessary, plus information on exposure time, plus some information on the colorants in the artefacts. If for example, the light intensity at the manuscripts is 100 lux, and the curator advises that the lights are turned on by guards only when visitors enter, which is, on average, 3 hours per day most days of the year, this gives a light dose per year of 100 lx times 1000 hours = 100,000 lux-hours a year. Larger units can be expressed in million lux-hours units (Mlx h) (as in e.g. Appendix 4 of this chapter). The 100,000 lux-hours of the above example could therefore be expressed as 0.1 Mlx h. If the weakest colorant in the manuscripts is in the category of High sensitivity (a plant dye, for example) then we see from the table that if there is a UV filter on the lamp, then about 1 Mlxh will cause a just noticeable fade. That will take about 10 years. And if full fade takes about 30 times longer, then 300 years for full fade. So, in terms of the scales:

How soon? *(in the middle between 0 and 1)*	0.5
How much damage? *(this is a curatorial assessment, typically 1 - 2)*	2
How much of the collection? *(for example, consider it is a small museum)*	2
How important are the artefacts? *(for example)*	1
Total magnitude of risk	5.5

If one chooses to use an estimate based on the beginning of the fade, then the "How soon?" score rises to 2, but the "How much damage?" score drops to 0. The result is a total of 5, similar. Either approach is correct for purposes of assessment. If one knows that the colorants are all mineral pigments, except one red, which you know is madder, medium sensitivity to light, then it takes 30 Mlxh, almost 10 000 years for a full fade! It is better in such extreme examples to use the category of just noticeable damage (score 0) which occurs in 300 years (score 0.5) to obtain a total of 3.5 for the above example. This is a relatively small risk, not zero, but small.

Consider the possibility that the electric lighting was not 100 lux, but 2,500 lux, (common with modern spot lamps, and typical of indirect daylight in a room with an open window. Assume the displays were illuminated 12 hours a day, not 3. The rate of fading would increase 100 times. All the above totals would jump 2 points, to 5.5 for medium sensitivity colorants, and 7 for high sensitivity colorants, an urgent priority risk. In fact, if the display was already ten years old by the time the survey was made, any high sensitivity colorants would already be substantially faded. In the author's experience, staff find such results unbelievable, impossible, but I have seen many examples of museum exhibits of about 10 years age, where certain colorants were completely destroyed in that short period, although the artefacts were over a hundred years old. The fact is, ordinary people, scholars, owners, do not leave manuscripts and precious textiles under intense light day after day, year after year. Ironically, only museums, with a mandate of preservation, do that.

The options for reducing light fading risks are relatively few, and predictable.

1 Electric lighting hazards. Reduce lamp size and number. Cost: from low (lower wattage bulbs) to moderate (new lamp fixtures).

2 Daylight hazard. Block windows. Cost: from low (paint the glass, add curtains) to high (special shutters, blinds, building redesign). With very important manuscripts and unavoidable bright daylight in museums with windows, use photographic reproductions for display. Cost: price of a photograph.

Assessment of water risk in figure 9:

A surveyor needs to look up at the ceiling, perhaps above the louvers, and check for pipes. Also check the floor above, is there a bathroom? Laboratory sink? Suppose, for example, that the surveyor identifies a toilet in the floor directly above, plus 3 other pipes crossing the room. As a starting point, it is cautious but reasonable to estimate each such item may each leak once in 30 years. This is their expected life in industrial terms. So, 4 leaks in 30 years, randomly that is one event per 10 years. Estimate that each leak covers 1/10 the area of the room. So the risk assessment becomes:

How soon? *(one event each 10 years)*	2
How much damage? *(many water-based inks and paints may be lost)*	2.5
How much of the collection *(1/10 of the room gets wet each event)*	1
How important are the artefacts? *(as previous example)*	1
Total magnitude of risk	6.5

This magnitude of risk is in the level of "urgent priority", even though absolutely nothing may happen for 10 years, or even 30 years. This is the nature of "probable" loss. The surveyor cannot guarantee leaks, but as an advisor, the surveyor must warn based on probability. Still, the estimate feels wrong, looking at the picture.

It is wrong. The assessment above assumes open display. Pipes and plumbing above open display definitely create a high risk situation, (unfortunately common in modern museums that favour open displays). In figure 9, however, all manuscripts are in well-made cases, with tightly sealed glass lids. Close inspection of the detailing shows they would be very good at shedding water, especially the horizontal ones that slope. Many expensive new museum cases are useless at shedding water, or even worse than nothing, because they funnel water towards the artefact through lamp openings. Cases such as the one in figure 8, are very difficult to judge for water hazards. The author estimates perhaps only 1 in 30 books in the cases in figure 9 would get wet if all cases were sprayed with water. In addition, all the single vertically displayed manuscripts are encapsulated in plastic envelopes with sealed edges. About 1 in 10 of the plastic envelopes appears to have openings that would allow water from above to enter. (Plastic envelopes can be even better, I would estimate only 1 in 100 of those bags in figure 9 would leak even if the box filled with water.) So, for open books in cases, the risk drops 1.5 points, to 5, and for the encapsulated manuscripts inside the cases, it drops another 1 point, to 4, moderate priority.

The options for reducing the water risk are:

1. Rerouting the plumbing. Cost: moderate to high.
2. Establishing a special maintenance schedule for the plumbing above the display area.
3. Carefully inspecting and improving the case seals and encapsulation seals, especially under the pipes to make their ability to block water even better than estimated. Cost: low.

If a museum is considering design and purchase of many cases, or many cabinets for storage, and there is an unavoidable water hazard above, such as a water storage tank on the museum roof, it makes sense to design and test prototypes to resist water spray.

Exercise: Look at figure 8. How might you determine what is the risk of water entry from above?

Exercise: Go and look at one of your display rooms. Try to assess the risk of light fading, and the risk of water from above. Remember to begin by imagining the future, the next 100 years. Describe a scenario to yourself, then try to assess it with the scales. Focus - it is easier to begin with a specific type of artefact, a specific part of the room. Practice generalising later.

Figures 10 and 11. Two different boxes of small textiles, badges

Figures 10 and 11 are from two different small military museums in Canada. Like many museums, military museums collect costumes, textiles, and they collect large numbers of very small things that have value only as large sets of something. Looking at figures 10 and 11, one can see by now that the plastic food bags with "zipper locks" would be a very cost-effective way to reduce risk from water. It is also a way to reduce risk of tarnishing due to pollution. These could also be small items of clothing, shoes, hats, with metallic threads, from Islamic or ethnographic collections. Water and pollutant benefits can be estimated, perhaps not precisely, but with obvious scenarios in mind. Here, we consider the effect of the bags on two more difficult risk assessments: physical handling, and insects.

There is no doubt that collection conservators recognize the advantages of such bags, made with relatively heavy polyethylene, for protection from physical handling, and from insects. Curators like the advantages for reliable labelling, and for keeping fragments together. Label cards placed inside the bag strengthen even further, and make small pieces more visible. Natural history collections, archaeological collections, historical collections, all have such material. We know it is a good idea, but can the benefits be assessed meaningfully?

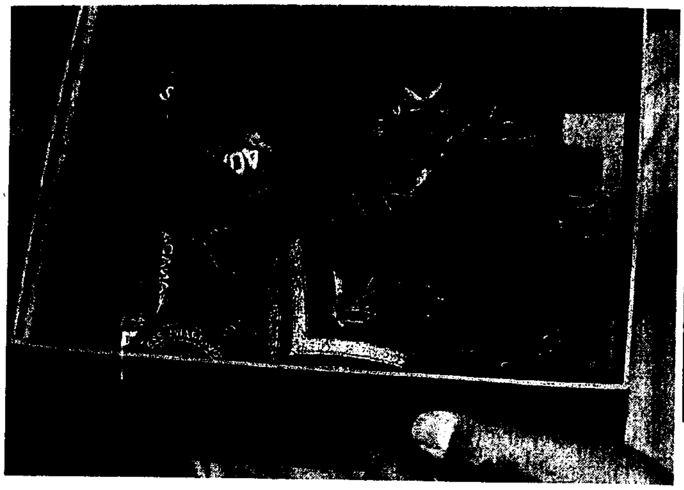

Figure 10. A box of military badges and textile insignia, without identification or separation from each other, in a small Canadian museum.

Figure 11. A box of military badges and textile insignia, each in an individual polyethylene "zip-loc" bag, most with identification cards inside, in a small Canadian museum.

For physical handling, the best information for estimates comes from the curators and collection managers or users themselves, especially in small museums where they are all the same person. In this particular example, the curator who had moved his insignia and badge collections into the bags was convinced that the rate of damage was much lower. The question for both curators, especially the one without a bagged collection, would be: How much damage do you estimate occurred to these objects from handling in the previous 10 years, or for as long as you have been in the museum in your memory? Such an estimate would include the effect of how often these objects were searched by users. Perhaps the museum anticipates a great increase in users, 10 times as many users per year would increase handling risk 10 times. These are certainly not easy assessments, but they are necessary before the museum can agree on the priority. If, of course, there is already an easier risk assessment, such as rate of silver tarnishing, or risk of water damage, or risk of lost labels, to justify the bags, then an estimate of physical force protection is informative, but not essential.

Figure 3. Solar boat, incorrect relative humidity risk? The museum building for the solar boat in figure 3 is obviously not typical of local historic architecture. It is the precise opposite of heavy walls, and small windows. It is what is known technically as a low mass building, and it has window area typical of a northern European yearning for light. True, it is called the solar boat, but it is also true the pharaohs (their technical advisers) buried it underground in a well sealed enclosure until 50 years ago. It is apparently a climate controlled building, but almost always that means temperature controlled for human comfort, and possibly the relative humidity is somewhere between 40%rh and 60%rh most of the time, and outside that some of the time. This is not flippancy, this is museum reality all over the world.

Exercise: How would you reliably determine the history of humidity and temperature?

Now the more difficult Exercise. If you did determine the humidity and temperature history, then what? How would you estimate risk?

There was a proposal many years ago, perhaps when the climate control appeared less than perfect, to place a very large amount of silica gel around the boat, which would act as a good humidity controller (called a "buffer". (See Thomson 1986, ASHRAE 2004, and other sources). Was it necessary?

Most readers will have learned that wooden artefacts show some degree of sensitivity to humidity fluctuations. Some learned it was very sensitive, others less so. The best currently available risk assessments to this question can be found in a very dense table available from the author. (The answer there: little to no risk of fracture for up to a 40% fluctuation in a structure like the solar boat, because each wood piece is free to expand and contract without constraint. This is, after all, designed like a boat, which gets wet and then dry without cracking. The pieces just get loose. The uncertain risk would arise if any pieces had been "restored" by a resin). A simplified but unfortunately vague risk estimate is implied in the ASHRAE table of Appendix 3. The fast, very precise answer is this: Humidity fluctuations cannot cause significant risk of fracture or delamination in the future unless they significantly exceed all fluctuations of the past. This past "worst rh fluctuation" is called the "proofed fluctuation of the collection" (long enough for the objects to respond), which in the case of the boat, which exceeds 1 cm thickness everywhere, is at least one full day, and probably many days for most elements. So, a very powerful benchmark for risk assessment is not science of the artefact, but history of the agent. With the solar boat, this is a double-edged sword. It was removed from a very stable humidity in a massive and sealed enclosure, and placed in a risky modern building in the desert sun. In other words, the risk, if any, has been taken already, unless the building performance deteriorates radically. And the boat looks OK after 50 years. Luck? I think not. I think the best available science suggests this type of wooden artefact has a very low sensitivity to humidity fluctuation. And I think the last 50 years proved that. So future collection managers can take advantage of the knowledge gained by the past. Two clarifications: 1, If there are small fractures and distortions observed in the boat, I suspect it is the long term average rh that is wrong, not all the fluctuations. I was informed that tests in similar burial chambers gave a steady 60% rh. And 2, note that there is no advantage whatsoever (aside from avoiding embarrassment) for a museum to exaggerate the perfection of its past climate control. Whatever happened in the past, happened. Its only value now is as data for future prediction. With humidity fluctuations and wood, leather, paint, textiles, glue, paper, parchment (and other organic materials) the greater the known risks in the past, the smaller the assessed risks for the future.

Exercise: What would you propose as a logical plan for estimating the "proofed rh fluctuation" of the wooden artefacts in your museum?

Exercise: The risks from the other three forms of incorrect rh do NOT follow the same concept as "proofed rh fluctuation". Damage accumulates for each event, such as damp, regardless of previous similar events. Explain.

Figures 12 and 13. Tutankhamun's lions

Figures 12 and 13 are presented as a cautionary tale about historical evidence. Unlike the solar boat, the artefact in figure 12 is showing clear signs of damage from incorrect relative humidity in 1986. Possibly rh fluctuations, possibly incorrect long term average rh. There is a tendency in museums to use such evidence as proof that

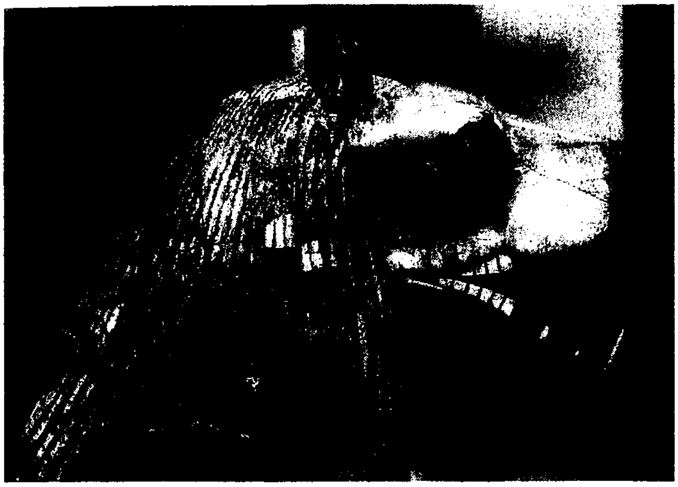

Figure 12. One of the lion heads in Tutankhamun's collection. Photographed 1986. Fracture and delamination of the gilded gesso layer, due to shrinkage of the wood components underneath. The question becomes, when did this damage occur? What are the risks from incorrect humidity and incorrect temperature for such an object?

Figure 13. The same lion head as in figure 12, in a photograph taken by the archaeologist the day the tomb was opened. Although the photograph is not very clear, each of the fractures or delaminations of 1986 is already present, but to a lesser degree.

the buildings current climate control systems are inadequate. It may be true that the building's systems were inadequate, but this particular evidence is weak. Notice in figure 13 that at the time of excavation, the artefact showed much of the same damage, at the same three locations. Access to more clear samples of the original photograph, and access to any available photographs between the two dates would allow a more precise interpretation of the evidence, and its implications for future risk management of humidity control.

Exercise: What important artefacts exist in your museum with similar evidence of slow accumulating damage from incorrect rh, or any other agent? Go and inspect them carefully. Are you able to deduce when in the past the damage occurred? What methods could you establish that would allow the museum to prove that in 1 year, or in 10 years, new damage had occurred?

Integrated risk management of pests (IPM)

Introduction

The material in this section is based on the work of Tom Strang of the Canadian Conservation Institute. His articles (Strang, 2001), and those of others (Pinniger, 2001) published recently in this area should be consulted when planning the museum's full IPM program, especially if insect damage is historically a known problem. Here, all the key concepts are provided, enough for a museum to understand the change from reliance on poison to reliance on IPM, and to begin its methods immediately. As noted in the previous section on integrated methods, the pest control industry adopted the concept and phrase long before museums. IPM is not only useful in itself, it is useful as a risk management model for all other agents of deterioration in museums.

Figure 14. Collection storage in a medium size museum. The overall tidiness is good, there appear to be no water sources overhead, and all but a very few of the large brass cooking vessels are stored without stacking one on top of another. As with many museums, there is a work space in the collection storage area which introduces many hazards, such as constant staff traffic, food, drinks, and considerable dust (in this example archaeological ceramics are being sorted and cleaned). It is not certain which tables are for work, which are museum artefacts.

Figure 15. A large museum display hall, 20 years ago, with traditional museum cases from almost a 100 years ago. The cleaners are dusting with a feather duster in the early morning. Daylight streams in. Whether anything is at risk here depends on what collections are present. Unlike the case of figure 7, one can easily clean underneath these cases, and inspect for insect resistance.

Avoid sources and attractants

Pests were the agent that initiated the addition of the word "attractants" to this control phrase. Pests cannot be avoided in the external environment, but unlike pollutants, and just like thieves, pests do follow paths towards whatever attracts them. And a fundamental attractant and pathway for pests is a pleasant habitat. One can become specific: the worst attractants are those that mimic the vulnerable collections. Fur, feathers, and wool in collections are especially vulnerable to certain insects, and those insects are attracted towards the museum building by, of course, fur, feathers, animal hair, and anything with the same material (keratins) or similar material (chitins) such as dead insects. Thus, habitat includes the trees and bushes that attract harmless birds and insects, which die, and then become the dangerous attractant. After insects clean-up those items, they look for more...in your building nearby. Vermin and insects in general are also attracted by garbage, especially food garbage. Garbage should be kept at least 20m away from the museum building, and emptied frequently. To repeat, the fundamental principle of first stage IPM: remove as much habitat from the surrounding area as possible. This applies to every layer of the nested enclosures of figure 5. One of the large advantages of display cases designed as in figure 15, as compared to that in figure 7, is that one can successfully ask cleaners to clean up dust (human skin flakes, hairs, etc) from under cases, i.e., habitat.

Avoid does apply directly to sources as well. Insects often enter the museum in new artefacts, or building materials, and often the materials for open exhibit display. Thus another general principle of IPM: quarantine and then inspect all incoming materials, especially the same type of material as your most important or most common collections....wood for wood insects, wool for wool, etc.

Block pathways

The nested enclosures of figure 5, the reliable walls, roof, doors, windows, of the "list of the basics", all speak to IPM. As do the plastic bags of figure 11, containing their precious bits of military wool. On a less obvious level, IPM speaks of a "sanitary perimeter" around the building, which can be applied methodically around each layer of the nested enclosures of figure 5. Conceptually, this overlaps with removing habitat, but it addresses the specific idea of the narrow band of habitat that acts as a pathway towards the holes and cracks in the enclosure.

Screens are an important detail, as are any openings over 1mm. Insect screens on windows, while common in some parts of the world, are absent in many others. Any museum with especially vulnerable collections, such as woollen textiles, should consider screens on any open windows leading into those collections, and on any ventilation openings for the mechanical systems.

Probably, one of the lucky factors for museums in hot dry climates, given the lack of screens on windows, was the concurrent lack of vegetation and habitat around the building. It is a great irony, and unfortunate reversal, that modern museums in these countries strive heroically to provide pleasant landscaping, watered gardens, restaurants, all to attract pests to their oasis, and then their collections! Such museums should at least consider the sanitary perimeter concept, i.e., a 1m border of grass and shrub free gravel around the entire building, and special care with garbage removal.

Detect

Adult insects enter a collection, find their habitat, and lay eggs. The larva and or pupa stage destroys your artefacts, becomes adult, and spreads through the collection. This cycle typically takes a few weeks, so it is vital to detect any infestation before the cycle can repeat. If it repeats two, three times, before you discover it, losses will escalate exponentially. One of the most useful methods to emerge in museum IPM in the last two decades is the systematic use of insect "sticky traps". Although sold to home owners as a means of killing insects, their use in museums is not for killing per se, but for detecting. These sticky traps are placed throughout the collections, especially along insect pathways (the dark edges of walls, etc) then inspected on a regular interval, perhaps once per month. It is important to identify the species of insect, since many are harmless to your collections. (see References for identification sources) Then it is important to maintain records of what you find, and where, and finally, it is important to notice any "hot spots" in your building, and to respond.

Respond

In brief, kill the pests. More precisely, find the infestation that has been detected by the sticky traps, or by routine inspection of the collections, or in the quarantined incoming material, and isolate it immediately, and gently. Dispersing adult insects throughout the collection by uncovering everything is not useful. Wrap in plastic to start, and seal well. Consult the literature, and experts (genuine experts, not purveyors of poisons) for more details. There are several new methods of killing insects that museums need to know, which avoid poison. One group are called "controlled atmospheres" or "anoxia" and rely on a bag filled with air that has no oxygen. The other methods are called "thermal" and use either very high, or very low temperatures. (Strang, 2001)The high temperature methods can use extremely low cost techniques, such as placing infested artefacts in black polyethylene in the sun for one day. This "solar" method is now well described in the collection preservation literature. (Brokerhof, 2002)

Integrated, sustainable risk management of lighting, pollutants, temperature, and humidity Risk management replaces rigid standards for the museum environment

Worked examples of the section Examples of specific risk assessments and individual solutions presented a risk assessment and risk reduction approach to issues such as lighting and humidity control. As noted at the beginning of this chapter, most preservation advice and guidelines use a much simpler approach, based on "best-practice" or "standards". This is especially true of the last four agents of Table 1, lighting, pollutants, incorrect temperature and incorrect humidity, known collectively as the "museum environment." Simple rules are much easier to specify, but the price can become very high, and the benefits arbitrary.

During the 1970s, museums worldwide adopted simple rigid standards for the "museum environment". These standards were based on extremely cautious estimates of some risks, and oversimplification, or complete omission, of other risks. The targets were unnecessarily difficult and expensive in some situations, and counter-productive in other situations. Although museums are gradually replacing these rigid targets with more flexible guidelines, the rigid targets still dominate much of the published advice. They completely dominate loan agreements between museums, an important fact for large museums that want to borrow exhibitions.

The dominant text for the past quarter century in this area has been *The Museum Environment* by Garry Thomson (1978, 2nd edition 1986). It still provides an excellent overview of many issues, although some of its material is now dated.

Museum lighting guidelines

For many decades, the lighting standard in museums stated that textiles and works on paper should be illuminated at only 50 lux and paintings and other painted surfaces 150 lux. (Lux is the SI international unit of light intensity). For comparison, full sunlight can be up to 100,000 lux, indirect daylight 10,000 lux, bright spotlamps are 2 000 lux, office lighting typically aims to provide 750 lux on the desk, and a candle held an arm's length away shines 1 lux on you.)

Several complications arose. Older viewers cannot see details at 50 lux – the usually recommended lighting level for light-sensitive textiles, watercolours and manuscripts, while even young viewers cannot see complex or dark surfaces well at that lighting level. Many artefacts are not very sensitive to light, and are kept in the dark for no good reason. On the other hand, many others are so sensitive to light that continual illumination even as low as 50 lux will cause fading after many years of permanent display. The author has reviewed all the literature on visibility, as well as all the useful data on textile fading, and developed a general lighting guideline. (Michalski, 1997)

In the last ten years, risk management has emerged in lighting guidelines from other authors. All begin with the same risk assessment approach, i.e., how soon until noticeable fading? Different authors provide different strategies to simplify the decision across varied collections. Eventually, however, all lighting guidelines based on an acceptable time to cause noticeable fading need data on sensitivity of collections to light. The best summary of such data has appeared in a recently published international guideline for museum lighting (CIE 2004), and is presented in a shortened form in the Appendix Sensitivity of coloured materials to light.

Alternatively, one can decide to maintain the traditional rigid guideline, light all artefacts at a very low level, such as the 50 lux to 150 lux range, and accept the complications listed earlier.

Museum temperature and humidity guidelines

For several decades, the standard in humidity and temperature advice was simple, and rigid: aim to achieve 21°C with 50% RH, and very little fluctuation permitted. This standard grew out of a concern for paintings and furniture in Europe, and was indeed beneficial to those collections. Unfortunately, it was not at all beneficial to modern archival and paper materials, which needed cool and dry conditions for long life. (Michalski, 2000) It was not beneficial to corroded metals, which needed dry conditions. It was unnecessarily stringent for many collections, such as paintings, wooden artefacts, parchment, which were at serious risk only from damp and extreme dryness, or stone, ceramics, stable glass, and clean metals, which were at serious risk only from damp. Finally, as noted under sustainability, it was an expensive standard to implement at a building level.

In 1999, a committee of conservation scientists and mechanical engineers in North America agreed on a more precise set of guidelines. These were published in a new chapter for museums, libraries, and archives in the US engineer's handbook, first in 1999, and revised in 2003. (ASHRAE, 2003) The chapter also contains an excellent review of the types of risk to museum collections, based on the subtypes of incorrect temperature and incorrect humidity given in the agents of Table 1. The recommended temperatures and humidities from the ASHRAE chapter is provided in Appendix 3. Anyone considering design specifications for a building, however, should obtain the entire chapter, for themselves and for the consulting engineers.

The ASHRAE specifications (Appendix 3) use the risk management concept. There are several grades of fluctuation control, AA,A,B,C,D, and the risks of each grade are listed in the right hand column of that table. Also listed is the risk to chemically unstable archival materials whenever temperature near 21C is chosen. Note also that when designing a temporary exhibit space to receive borrowed exhibits, the space must be designed to meet the lenders climate requirements, which are usually very strict.

In the author's experience of desert or near desert climates, the periods of sustained damp that plague maritime and tropical regions are uncommon. Rooms below ground are unusual in the traditional architecture, so continuous damp from below ground storage does not often arise. The most common hazards are very high average temperature and extreme fluctuations in temperature and relative humidity between day and night.

The risks of high temperature are actually not large for traditional materials. They are a serious problem for photographs, paper of the last 150 years, plastics, audio-visual material, and digital media. The risk is very rapid decay, unless cooling equipment is used. Thus the preservation of modern archival materials does require modern building technology.

Fortunately, metals, ceramics, glass, wood, leather, parchment, rag paper, oil paint, natural resins, and animal glue experience relatively low risk from occasional air temperatures up to 40°C. Thus traditional materials in museums and archives, such as parchment, papyrus, and rag paper, rarely are seen to have suffered loss from dry heat. When seen in poor condition, the responsible agents are almost always damp, physical forces (poor handling), insects, pollutants, UV and light. (This is not to justify outdoor exposure in desert sun. This obviously destroys these materials in a few years, due to very intense UV, and surface temperatures of 100°C or more in direct sun.)

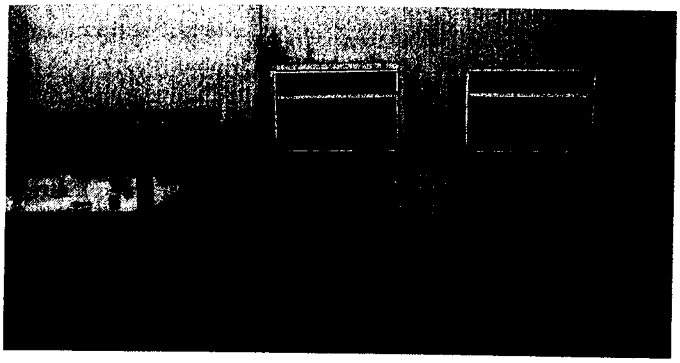

Figure 16. Typical small museum and the ubiquitous modern air conditioners. These often cause as much harm to artefacts as comfort to visitors and staff. They often cause high RH where it never existed before, and a source of water drips (condensation) where it never existed before.

In maritime regions, i.e., near the sea or the ocean, sustained damp can become a problem. In modern European style buildings with storage below ground, and a high water table due to a river nearby, then sustained damp can also be a problem. In the author's experience, the single most common cause of damp in small museums in hot climates is air-conditioning equipment, as in figure 16. It invariably malfunctions, and the sad fact is that air-conditioning often brings the first exposure of museum collections to high relative humidity (and another source of water leaks). Always keep artefacts sensitive to water or damp away from air conditioners. If you plan to install a new air-conditioner, monitor the rh before installing for some weeks or months if possible, and then monitor carefully after installing and operating the air-conditioner.

Humidity fluctuations pose a moderately high risk, and some examples of risk assessment were provided in the section Examples of specific risk assessments and individual solutions 6. The concept of "proofed rh" introduced in that section is critical to an estimate of risk from fluctuating rh. Note that an air-conditioner, for example, if it introduces new and larger rh fluctuations, may exceed the proofed rh of your collections.

In any situation where relative humidity is in question, human perception is generally unreliable (except for extreme damp.) Relative humidity must be measured (Detect stage) in order to make an accurate risk assessment.

Museum pollutant guidelines

Airborne pollutants are gas, liquid, or solid contaminants carried by the air that are known to cause damage to objects. Most of us are familiar with external sources such as urban pollution, desert sand, sea-spray, but museums must also consider internal sources, such as building materials and packaging materials that emit gases.

Traditional guidelines on museum pollutant specifications followed two lines of reasoning: natural levels don't appear very harmful, and, when in doubt, ask for the best available filtering systems. Thomson (1986) proposed the benchmark of naturally occurring pollution levels, since it had been observed that archive collections far from urban areas could survive undamaged for centuries, while those in urban locations often suffered within decades. This was a useful approach for pollutants that occur naturally at some significant level, such as sulphur dioxide and ozone, but it was not useful for pollutants that occur naturally at extremely low levels. For such pollutants, there was a tendency simply to ask for "best available technology" in specifications of mechanical systems. In practice, very few museums actually built best-available systems.

Recently, Tétreault at the Canadian Conservation Institute introduced a risk management approach to pollutant guidelines, based on the concept of "observable adverse effect" (OAE). He coined the related terms No Observable Adverse Effect Level (NOAEL) and Lowest Observable Adverse Effect Dose (LOAED). These terms have been incorporated in the pollutant guidelines in the ASHRAE engineers' handbook, (ASHRAE 2004) and are explained in detail in a comprehensive manual on pollution by Tétreault (2003). Whatever the formal terms, however, one can recognize the same risk concept as used in lighting guidelines, that of a noticeable, or observable, loss. More precisely, it is a "just noticeable" or "just observable" loss. The artefact will then continue to fade or tarnish or decay for many more doses. In the case of light fading, for example, it takes about 30 to 50 more such doses before all colour is lost. While data presented in the form of "just observable effect" is useful in setting targets, it must be used carefully in a general risk survey, because it defines the beginning, rather than the end, of a cumulative risk. Fortunately, the risk assessment scales can cope with this difference, as clarified in some of the examples earlier.

Applying pollutant guidelines becomes very complex very fast. Unlike light, which is an agent with no subcategories, and with only one type of risk, fading, pollutants consist of dozens of particulates and gases, each with different sources, different forms of risk, different rates of damage, and different collections that are attacked. Fortunately, there is a list of the basic pollution problems which arise because either the pollutant is very widespread in its damage, such as heavy dust, or because a particular combinations of pollutants and artefact materials lead to very rapid chemical reaction. Museums have suffered from these situations over and over. Table 4 lists these.

Note that the risk reduction methods collapse into just two approaches, one for external pollutants, and one for internal pollutants. External sources are controlled primarily by the Block stage, and internal sources are controlled primarily by the Avoid stage.

Consider the problem of colorants in manuscripts. Research has shown that pollutant levels at the worst levels observed in urban situations can completely fade the most sensitive colorant in about a year, if the colorant is freely open to the polluted air. We know, however, that watercolours and manuscripts have survived very well over many centuries, even in some cities with historically heavy pollution. Why? Because of protection provided by a closed book, a sealed glass frame, closed wooden box, a closed leather pouch, even an envelope.

Scientific models show that compared to open air, a tight glass frame or a tightly closed book can reduce entry of the pollutant by a factor of 100 to 1000. In other words, the worst urban pollution hazard that brings a risk of complete colour loss in one year, is reduced to complete loss in perhaps 300 years. Thus, on the risk assessment scale, for the same urban pollution hazard, the risk drops 2-3 points on the "how soon?" scale if a tight glass frame is used. Furthermore, one can adjust all these

Table 4. The basic pollution problems (abridged from Tétreault (2003) hypersensitive materials table, plus other sources)

Pollutants	Sensitive material	Risk	Hazards, Sources	Risk reduction methods
External sources (primarily)				
Particles, especially silicates (sand) carbon (smoke)	All artefacts, especially if porous, complex surface.	Soiling. Accelerated corrosion of bright metals. Damage during subsequent cleaning.	Blowing sand, dust. Urban pollution, especially traffic.	Enclose artefacts in airtight cases, packages, cabinets. Reduce outside air entry to building, especially during peak traffic, or peak dust storms. Operate building system filters.
Ozone Nitrogen dioxide Sulphur dioxide	Some colorants in watercolours, illuminations (indigo, crimson, basic fuchsin, curcumin.)	Colour fading	Urban pollution especially traffic	
Internal sources (primarily)				
Hydrogen sulphide	Silver	Silver tarnishing, (and subsequent abrasive cleaning.)	Rubber compounds. Wool when exposed to UV. Humans.	Avoid all listed sources inside display cases. Avoid all listed sources in rooms and furnishings. Seal or coat any source used in construction.
Carboxylic acids	Lead. Carbonates, such as shells.	Lead tarnishes. Shells effloresce.	Wood and wood fibre products. Oil and alkyd paints. Water based paints while fresh.	

estimates by the benefits of closed buildings, which have been shown to lower concentrations by three to ten times below outdoor levels. The important point in all these estimates, however, is that by far the most important, most predictable, most cost-effective risk reduction was the simple glass frame. Next we see how enclosures can become the problem, not the solution.

A considerable body of conservation literature addresses the issue of safe and dangerous display materials, and how to test them, all reviewed in the text by Tétreault (2003) and in his shorter publication on coatings (1999) A new and excellent database on the web, provided by the Center for Conservation in Quebec, Canada, describes the uses and dangers of many materials used in museum exhibits and storage. (http://preservart.ccq.mcc.gouv.qc.ca)

In the author's experience surveying museums in Arabic countries, the single-most common pollutant problem is not urban gases, but particulates: sand and dust, augmented often by carbon from diesel engines on buses and trucks. Commonsense tells everyone that a closed case, closed cabinet, closed envelope, box, whatever, reduces the risk of this hazard. In figures 8, 15, artefacts in cases are successfully protected from dust, from any source. Museums exhibit designers, however, often want open display, or the museum simply lacks the resources to enclose large objects. The daily cleaning of the museum then leads to other problems outlined earlier in the section on housekeeping, and illustrated in figure 7.

Integrating management of all four agents

These four agents, pollutants, light/UV, incorrect temperature, and incorrect humidity, have many features in common, each of which suggests paths for integration.

A All four are "scientific" agents of deterioration, the ones of modern knowledge. The preceding five agents (#1 to #5) are ancient in their understanding.

B All four can be measured precisely by scientific instruments, or meters. In fact, unlike the preceding five ancient agents, their intensity is not easily estimated except by instruments.

C All four are strongly associated with engineering and design of the building, and of exhibits and storage fittings.

D All but light/UV move towards the artefact by air movement.

E All but incorrect temperature can be blocked by thin, low-cost, even delicate materials.

Implications of A and B. The fact that these agents are scientific, and that they can be measured, has been a double edged sword in museum integration. On the one hand, modern conservators and scientists were comfortable with scientific agents, learned how to measure them, and had integrated them into a single practical concept: "the museum environment." Museums accumulated a great deal of environmental data, and even curators became familiar with light meters and thermohygrographs. On the other hand, conservators and their scientists tended to lose sight of the more ordinary, unscientific hazards, such as poor handling, pests, water, even dirt.

The museum should have access to a light meter, UV meter, humidity meter, and thermometer. Many countries have discovered the advantage of using a central regional or national agency that lends these instruments as a kit to smaller museums who don't have the resources to purchase or calibrate them. Pollutant measurement is more complex. Some important indoor museum pollutants can be measured using simple colour dosimeters. External pollutants are usually measured by other agencies, and the information can be obtained from them. An excellent review of the possibilities of pollutant measurement is in Tétreault (2003).

Implications of C and D: Integrated control of museum climate and lighting will require mutual understanding between designers of all the building systems and all exhibition and storage systems.

Implications of E: Many risk reduction solutions to contaminants, UV, light, and incorrect humidity require little more than an opaque bag of clean material. Hence one of the basic strategies listed in the List of Basic Strategies earlier.

Conclusions: Keep going

The intent of this chapter has been to teach an attitude and a skill that can lead to effective collection preservation. It could not review all the necessary information, only draw on useful examples. The professions of conservator/restorer, and of conservation scientist, however, are well served by a body of technical literature, easily located through publications, and increasingly, well served by the Web (see the References at the end of the book).

Figure 17. Teamwork and training. Young conservators and conservation scientists during a training exercise in a museum. They are learning the use of light meters and humidity meters, and some basic elements of a collection survey. The case in front of them holds a pile of bronze coins, fused together in a corroded mass with sand, and displayed to show how such hoards are found by archaeologists.

What has struck the author repeatedly, throughout the world of museums, is that in spite of great good will on the part of staff, a remarkable fragmentation and inconsistency in preservation strategies is the common. Long-term effective preservation depends on risk management, on integrated methods, on teamwork, and on sustainability. Those responsible for preservation of collections must understand these ideas, and gradually convince others in the museum, before they can achieve them.

Figure 17 is a fitting place to end this chapter. It shows a group of young conservators and conservation scientists in Egypt, on a training exercise five years ago. They are learning the use of environmental monitors, such as light meters, and the basics of surveying an exhibition building for this particular agent. It is a bridge between their normal work, which involved no surveying at all, and a possible future task for some of them, of leading a complex survey of all risks to the collection. The exhibit case they are all resting on while they discuss and share light readings contains a coin hoard, placed in the case by the designer to show how archaeologists discovered them. It is a cemented mass of corroded bronze and dirt, showing the classic pale green colour of contaminated and actively corroding bronze, resting in a case perched on one leg. Exercise: What are the risks? How significant are they? How can you find out? What would you advise the museum? We need the report next week...

Appendices

Appendix 1. The visible facts: A suggested survey path, basic set of observations, and set of photographs

General comments: Although the photo sequence will help organise photos, it is essential to record the photo number alongside any notes about observations, and to note in observations which room, which door, which collection, etc.

Although the ultimate purpose of a risk assessment survey is to discover the risks to a collection, remember that the survey is only a first phase in collecting facts that will be used to estimate significant risks to the collections. Of course, during a survey one will see and understand many risks, and this will help in collecting the most useful observations, but make observations even if the door or wall or packaging is "good". In any systematic survey, such as this one, or Waller's (2003) one makes estimates about all agents and all collections, so that the report describes both the good and bad aspects of current risk management of the collections. Diplomatically, most museums like a report with some positive observations!

Site

Walk: Around the whole site, 10m to 50 m away from the building

Photos: Overall views (wide angle) of site from front of building, from left side, back, right side.

Observations to collect:

Type of buildings nearby, or attached? (source of fire, water, thieves, vandals)

Slope of the land nearby, the height/distance to nearby rivers and drains? (water)

What public water and drainage and sewage systems can you see? Do they appear in good condition? (water)

Fire hydrants available nearby? (fire)

Lighting for night surveillance? (thieves, vandals)

Building Perimeter

Walk: Around the building perimeter, looking at the walls and roof (If necessary, later get access to a view of the roof)

Photos: Overall views (wide angle) of front, right side, back, left side, of the building.

Observations to collect:

Wall materials, gaps, quality of construction? Cracks? Gaps? (block all agents of deterioration)

Wall vents? Do they have screens? (block pests, thieves)

Night lighting? Clear lines of sight? (thieves, vandals)

Perimeter near building clear of vegetation. Garbage stored nearby? (pests)

Roof construction? Sloped or flat? Type of drain system? Condition? Signs of failure? (water)

Any other obvious hazards related to the building perimeter?

Doors and windows

Walk: Around the building perimeter, looking at the doors and windows (If necessary, later get access to the inside view of each door and window)

Photos: Identify each different type of door. Make at least one photo of each type. Any doors with special problems, make a photo. Take close-ups of locks, gaps, any problems of poor condition (always take these in sequence with the overall photo of that door/window.)

Observations to collect:

Door materials, locks, hinges, gaps, seals, quality of construction? (ability to block all agents)

Window materials, locks, gaps, seals, screens, quality of construction? (ability to block all agents)

Screens, curtains, blinds? (thieves, vandals, light, UV)

Where they open at the time? Why? (ask staff)

Any other obvious hazards related to the doors and windows?

Non-collection rooms

Walk: Through all rooms and halls without any collections

Photos: Wide angle view of each room, one towards door, one opposite. Close-up of any relevant observations.

Observations to collect:

Loading bays: type and height of access ramps (risk of dropped artefacts)

Quarantine rooms: use, access (pests)

Janitors rooms, washrooms: sinks, plumbing, overflow drains (water)

Food preparation and service rooms: as above, plus garbage, cleanliness (pests)

Hallways, elevators: ease of access, obstructions, cleanliness (physical forces in transit, pests)

Collection Rooms

Walk: Through each room with collections. Display first, in visitor's sequence, then storage. Within each room, walk around the perimeter several times, looking carefully, before making photos or notes. Finish all rooms before surveying fittings or collections.

Photos: Wide-angle of each of 4 directions, each taken from as far away as possible. First wall with door, then proceed clockwise. If the wall photos do not show all the ceiling and floor, take separate photos of the ceiling and floor. For each significant observation below, where a particular risk is identified, take a close-up.

Observations to collect:

What floor (i.e., height above ground) is this? (water risk from flooding)

What fire systems visible (sprinklers, portable, detectors)?

Special mechanical systems? (pollutant, temperature, rh, control, water)

Plumbing visible overhead, on walls, near floor? (water)

Floor drains, placement, stop-valve, condition? (water, draining, and backup)

Electric lighting systems, lamps types, lux levels average, maximum?

Which doors and windows from the building survey are used in this room? (ability to block all agents)

What wall materials, gaps, quality of construction? (ability to block all agents)

Any other obvious hazards related to the room?

Fittings

Walk: In each room, identify the various types of fittings (cabinets, cases, shelving, barriers for visitors). Make a note of the number of each type, and how many are in each room. It is not necessary to segregate similar fittings, unless the difference has a significance to risk.

Photos: At least one overall photo of each type of fitting, and some close-ups of construction, locks, gaps, any examples of damage, or other risk issues.

Observations to collect:

Materials of construction, of glazing? (ability to block agents, source of contaminants)

Quality and condition, gaps? (ability to block agents)

Security features, locks?

Ability to shed water?

Stability against toppling, collapse? (physical forces, vandalism)

Lighting fixtures, lamp type, lux levels, UV filters, quality and condition? (UV, light, incorrect temperature and rh, fire)

Any special control features for humidity, pollutants?

Any other obvious hazards related to the fitting?

Collections, supports, and packaging

Walk: By now in the survey, the collections will have been observed several times while surveying the rooms and fittings. It is a time to reflect on how to survey the collections, their supports, and their packaging. The purpose of this collection survey is not to capture a detailed view of each artefact. That is one of the purposes of a good catalogue. The purpose is to discover the current pattern of risks. Some observations can apply to all the collections, some observations can apply to one special artefact, but only if it is very important.

Photos: Photos will now be associated with each observation.

Observations to collect:

Type of supports, materials, quality, on how much of the collection ? (physical forces, contaminants)

Type of packaging, materials, supports, on how much of the collection? (ability to block many agents, source of contaminants)

Finally, very important: What portions of the collections are in what nested sequences of building, room, fitting, support, and packaging (or partial sequence, or on the floor, or outside, etc.? This will lead to the identification and estimates of risk, and to recommendations for improvements, in combination with invisible facts of Appendix 2. Remember, this survey pattern collects facts systematically, both positive and negative, which then lead to risk assessments, low and high. One can choose instead, as do many experienced surveyors, to only collect observations that lead to estimates of significant risks. Better to report the positive survey observations without a risk estimate (e.g., food garbage is removed daily to a location 30m from the building) even if there is a related significant risk elsewhere in the report (over a 2 week test, large numbers of insects were collected in sticky traps in the collection rooms, and these showed a clear increase at the wall nearest the food service area. Fortunately none are clothes moths, but a high probability of a clothes moth infestation in the open textile collections is indicated within a few years.)

Appendix 2: Basic list of invisible facts needed, and their sources

Staff interviews

What damage has occurred in the past to the collections? What were the circumstances?

For staff members inside and outside conservation, what are their formal roles and responsibilities in collection preservation? What are their opinions and understandings of the practical realities?

Documents

What are the policies and procedures of the museum, especially related to the collections?

What reports exist of prior risks, events, planning reports?

Building, facilities, exhibits construction?

External data

External hazards, probabilities?

Answers to all the questions needed to complete the various risk estimates?

Appendix 3. Temperature and relative humidity specifications

Compiled by Michalski, S. Canadian Conservation Institute for use in the ASHRAE handbook, first published 1999, and later 2004 (ASHRAE 2004).

COLLECTION TYPE	SETPOINT OR ANNUAL AVERAGE	MAXIMUM FLUCTUATIONS AND GRADIENTS IN CONTROLLED SPACES			COLLECTION RISKS/BENEFITS
		Class of control	Short* fluctuations plus space gradients	Seasonal adjustments in system setpoint	
GENERAL MUSEUMS, ART GALLERIES LIBRARIES AND ARCHIVES: all reading and retrieval rooms, rooms for storage of chemically stable collections, especially if mechanically medium to high vulnerability.	50%RH (or historic annual average for permanent collections) T: A value between 15°C and 25°C (Note that rooms intended for loan exhibitions must be capable of the setpoint specified in any loan agreement, typically 50%RH, 21°C, but sometimes 55%RH or 60%RH).	AA Precision control, no seasonal changes	±5%RH ±2°C	RH: no change up 5°C; down 5°C	No risk of mechanical damage to most artefacts and paintings. Some metals and minerals may degrade if 50%RH exceeds a critical RH. Chemically unstable objects unusable within decades.
		A Precision control, some gradients or seasonal changes, not both	±5%RH ±2°C	up 10%RH, down 10%RH up 5°C; down 10°C	Small risk of mechanical damage to high vulnerability artefacts, no mechanical risk to most artefacts, paintings, photographs, and books. Chemically unstable objects unusable within decades.
			±10%RH ±2°C	RH: no change up 5°C; down 10°C	
		B Precision control, some gradients plus winter temp. setback	±10%RH ±5°C	up 10%, down 10%RH up 10°C, but not above 30°C down as low as necessary to maintain RH control	Moderate risk of mechanical damage to high vulnerability artefacts, tiny risk to most paintings, most photographs, some artefacts, some books and no risk to many artefacts and most books. Chemically unstable objects unusable within decades, less if routinely at 30°C, but cold winter periods will double life.
		C Prevent all high risk extremes.	Within range 25%RH to 75%RH year-round T rarely over 30°C, usually below 25°C		High risk of mechanical damage to high vulnerability artefacts, moderate risk to most paintings, most photographs, some artefacts, some books and tiny risk to many artefacts and most books. Chemically unstable objects unusable within decades, less if routinely at 30°C, but cold winter periods will double life.
		D Prevent damp.	Reliably below 75%RH		High risk of sudden or cumulative mechanical damage to most artefacts and paintings due to low humidity fracture, but high humidity delamination and deformations, especially in veneers, paintings, paper and photographs will be avoided. Mould growth and rapid corrosion avoided. Chemically unstable objects unusable within decades, less if routinely at 30°C, but cold winter periods will double life.
ARCHIVES LIBRARIES Storage of chemically unstable collections	Cold Store: -20°C 40%RH	±10%RH ±2°C			Chemically unstable objects usable for millennia. RH fluctuations under one month do not affect most properly packaged records at these temperatures. (Time out of storage becomes the lifetime determinant).
	Cool Store: 10°C 30%RH to 50%RH	(even if achieved only during winter setback, this is a net advantage to such collections, as long as damp is not incurred)			Chemically unstable objects usable for a century or more. Such books and papers tend to low mechanical vulnerability to fluctuations.
SPECIAL METAL COLLECTIONS	Dry room 0-30%RH	RH not to exceed some critical value, typically 30%RH			

* Short fluctuations means any fluctuation less than the seasonal adjustment. As noted in the text under "Response times", however, some fluctuations are too short to affect some artefacts, or enclosed artefacts.

Appendix 4. Sensitivity of coloured materials to light

This is an abbreviated version of the table compiled in 1999 by Michalski, S. at the Canadian Conservation Institute, and published in CIE. (2004) For more detailed lists of colorants under each category, see the CIE table. For textile dyes alone, see the table in Michalski (1997.)

	High sensitivity to light			**Medium sensitivity to light**			**Low sensitivity to light**			**No sensitivity to light** [f]
	Most plant extracts, hence most historic bright dyes and lake pigments in all media:[9] yellows, oranges, greens, purples, many reds, blues. Insect extracts, such as lac (yellow), cochineal (carmine) in all media.[9] Most early synthetic colours such as the anilines, all media. Many cheap synthetic colorants in all media.[9] Most felt tip pens including blacks. Most dyes used for tinting paper in this century. Most photo colour prints with "color" in the name. e.g. Kodacolor			A few historic plant extracts, particularly alizarin (madder red) as a dye on wool or as a lake pigment in all media. [9] It varies throughout the range of medium and can reach into the low category, depending on concentration, substrate, and mordant. The colour of most furs and feathers. Most photo colour prints with "chrome" in the name, e.g. Cibachrome.			Artists palettes classified as "permanent" (a mix of truly permanent AND low light sensitivity paints , e.g. ASTM D4303 Category I; Winsor and Newton AA.) Structural colours in insects (if UV blocked). A few historic plant extracts, especially indigo on wool. Silver/gelatine black and white prints, not RC paper, and only if all UV blocked. Many high quality modern pigments developed for exterior use, automobiles. Vermilion (blackens due to light)			Most but not all mineral pigments. The "true fresco" palette, a coincidence with the need for stability in alkali. The colours of true glass enamels, ceramics (not to be confused with enamel paints). Many monochrome images on paper, such as carbon inks, *but the tint of the paper and added tint to the carbon ink are often high sensitivity, and paper itself must be cautiously considered low sensitivity.* Many high quality modern pigments developed for exterior use, automobiles.
Blue Wool categories	1	**2**	3	4	**5**	6	7	**8**	Over 8	
Mlx h[a] for noticeable fade[b] UV presentc	0.22	**0.6**	1.5	3.5	**8**	20	50	**120**		
Probable Mlx h[a] for noticeable fade[b] if no UV[d]	0.3	**1**	3	10	**30**	100	300	**1000**		

Explanatory notes to table:

The "Blue Wool categories" are the international standard (ISO) categories for specifying sensitivity to light, based on 8 blue dyes on wool, used as reference samples in most lightfastness tests.

a. Mlx h is the unit of light exposure, or dose. Megalux hours. It is light intensity (lux) multiplied by exposure time (hours)

b. A noticeable fade is defined here as Grey Scale 4 (GS4) , the step used in most lightfastness tests as noticeable. It is approximately equal to a colour difference of 1.6 CIELAB units. There are approximately thirty such steps in the transition from a bright colour to almost white.

c. UV rich refers to a spectrum similar to daylight through glass. This is the spectrum generally used for the lightfastness data used to derive this table. The exposures here are the best fit to data that varies about one Blue Wool step.

d. Exposures estimated for UV blocked light source are derived from a study on 400 dyes and the blue wool standards themselves. As such, it is only probable, and probably only for organic colorants. These estimates show minor benefit of UV filtration for low sensitivity colorants, but large improvements for high sensitivity colorants. For conservative estimates, use the UV rich scale.

f. "No sensitivity" to light does not mean guaranteed colour life. Many colorants in this group are sensitive to pollution. Many organic media will chalk or yellow or both if any UV is present.

g. The particular paint medium makes only small differences to fading rate, it is the colorant that matters in fading, not whether it is oil, or tempera, or watercolour, or acrylic. Media does, however, make large differences to rate of discoloration from pollutants such as ozone and hydrogen sulphide.