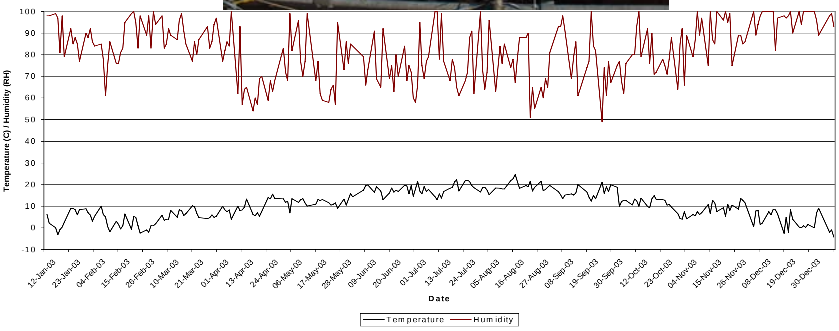
The Monitoring of Environmental Conditions under which BGS Data and Information (including Corporate Collections) are managed at Keyworth and Edinburgh: 2006

Information Management Programme

Internal Report IR/07/011



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/07/011

The Monitoring of Environmental Conditions under which BGS Data and Information (including Corporate Collections) are managed at Keyworth and Edinburgh: 2006

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Key words

Environment, Temperature, Humidity, Monologger, Thermohygrograph, Microtherm, Stevenson Screen, Core Store, Materials, Specimens

Front cover

Graph detailing weather readings at Keyworth & photograph of Murchison House 'weather station'.

(Photograph by G J Tulloch)

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BRITISH GEOLOGICAL SURVEY

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Foreword

This is the fourth report in the series of the ongoing study by the British Geological Survey (BGS) into the environmental conditions of certain storerooms under the control of the Corporate Collections Management Project at both the Keyworth and Edinburgh sites.

This year, the report series title has changed slightly to reflect the widening scope of the recording programme. For the first time, data from the two remote Edinburgh core stores at Loanhead and Gilmerton have been included.

Acknowledgements

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Eileen Callaghan is responsible for the downloading of the Edinburgh loggers on a weekly timetable. Eileen also highlights events she thinks I should be aware of, during Eileen's absence these tasks have fallen to Luis Albornoz-Parra and Leigh-Anne Baker. Graham would like to thank these colleagues.

I would also like to thank Ken Lawrie and Keith Holmes for their assistance with MS Access in presenting the half-hourly summed rainfall data and Willie Velzian and Simon Flower for their technical assistance with the weather station.

Thank you all.

Photograph credits:

Plates 1-5	Louise Neep
Cover photograph	Graham Tulloch

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Summary

This report presents the environment data gathered during the calendar year 2006 in the storerooms within which BGS Data and Information (including Corporate Collections) are managed.

The report follows the pattern laid down in the first of the series, released in 2004, *The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House 2002-03*, with comparisons made between data collected during the pervious year to assess the benefits or otherwise of modifications to either working practices or the fabric of the building.

1 Introduction into Environmental Monitoring

Monitoring the environment in sample stores is vital to the long-term strategy of the Corporate Collections Management Project. Recording fluctuations in the temperature and humidity within the store areas will, hopefully, pre-empt any potential problems with sample deterioration.

Standards in the Museum Care of Geological Collections, 1993 details the parameters in which rock & fossil material should be stored. Conditions outside these parameters or large variations within them can cause the acceleration of sample degradation, pyrite decay and efflorescence for example.

Without continual monitoring the environment of sample stores and therefore the possible threat to the samples cannot be accurately known.

As the conditions within stores was discussed in the report *The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House 2002-03* together with the strategy, equipment and the rationale behind the positioning of the various monitors and logging equipment it is not our intention to restate these in this volume unless there is an alteration to one of these factors.

1.1 AIMS AND OBJECTIVES

Strategy for Keyworth and Edinburgh

- To routinely monitor the temperature and relative humidity in all storage areas of the collections and, where possible, monitor the external climatic variations, to determine what affect this has on any climatic variations within the Collections.
- Interrogate data and report to the appropriate authorities any adverse readings, which may indicate a defect in the building, e.g. structural, heating or ventilation, to allow action to be taken to prevent any damage or further damage to the collections.
- Use our knowledge of the internal climates to store the collections in the most suitable locations, where possible.
- To randomly monitor temperature and humidity readings in individual storage containers within the collections to determine if a buffering effect, from variations in the main storage areas, takes place.
- Recommendations and improvements should be made as required, based on the data collected, in order to preserve the collections for future generations.

A summary detailing the Strategy for Environmental Control can be found in Appendix 1.

1.2 ENVIRONMENTAL CONDITIONS WITHIN MUSEUMS

Any geological collection or any other type of collection, however small it is, that has a significant importance to an institution or the public, should be carefully maintained and preserved.

One of the most important factors is to monitor and control the environmental conditions within the collections.

Numerous geological materials are sensitive to certain components of the environment, which include relative humidity (RH), temperature, atmospheric chemicals, light and vibration. Brunton *et al* (1985).

The main environmental conditions to affect any collection are temperature and relative humidity. Variations in temperature are associated with its relative humidity. As a volume of air is cooled, it becomes more saturated, and less saturated as it is heated. Therefore any major changes in temperature especially rapid fluctuations should be avoided. Temperatures below 10°C should also be avoided because of high humidity values and the risk of condensation. The ambient storage temperature for geological specimens should be between 16-22°C. Doughty *et al* (1993).

Any geological collection can be potentially damaged or destroyed by relative humidity and are therefore sensitive to changes in humidity in the environment in which it they are stored. High humidity levels can lead to deliquescence, chemical change such as pyrite decay, and deformation of some materials through the absorption of moisture. Extremely low humidity levels can cause efflorescence and shrinkage of some moisture absorbent specimens, including shale and sub-fossil bone. For general geological materials the ambient relative humidity should be around 45-55%. *Child* (1994).

In addition to maintaining acceptable conditions for the general collections, some geological specimens require storage under different conditions; these are specified in Table 1. For storage of non-geological specimens, such as documents on paper, these recommended conditions are shown in Table 2. Where storage conditions are required outside of these limits, conditioned microclimates must be used.

Material Type	**Ambient Temperature**	**Ambient Relative Humidity**
General Conditions	16-22°C	45-55%
Cold Store		
Fresh borehole material in a barrier film	4°C (+/-2°C)	n/a
Sensitive material		
Pyrites & Marcasite (and fossils containing these minerals)	16-22°C	< 55%
Fossils with shale or clay matrix	16-22°C	Not Below 40%
Sub-fossil bone, tusks, teeth (*Child*, 1994)	18-22°C	50-55%

Table 1: Ambient Storage Conditions for Geological Specimens (Doughty & Brunton, 1993 & Child, 1994)

Material Type	Ambient Temperature	Ambient Relative Humidity
Historical Records		
Documents on Paper - frequently used material	16-19°C	45-60%
infrequently used material	13-16°C	45-60%
Modern Records		
Magnetic recording media	Stored in an environment as close to that in which it will be consulted	

Table 2: Ambient Storage Conditions for non-Geological Specimens (BS 5454:2000)

1.3 AREAS OF INVESTIGATION

The monitoring for this report has been undertaken at four sites within the British Geological Survey (BGS). These are located at Keyworth, Nottingham, and Murchison House in Edinburgh and Loanhead and Gilmerton in the Edinburgh area.

1.3.1 Keyworth

The areas of investigation for this report include the Palaeontology Collections, Core Store (including the Petrology and Borehole Collection), together with the NGRC and now the Keyworth Library. In addition to this, meteorological readings from the BGS Keyworth weather station are also used for comparative purposes between external and internal environments.

The Keyworth site houses numerous types of collections that come under the category of Corporate Collections.

This includes the Borehole Collection, which contains over 3000 pallets of core from England & Wales, from 3000 boreholes. Together with over 600,000 registered samples from onshore UK boreholes and 1,500,000 cutting samples from 1,500 onshore UK oil wells.

The Palaeontological collection includes about a quarter of a million macro-palaeontological specimens of museum quality. Together with an additional two million specimens collected during mapping projects, which are still are of significant importance. This makes this one of the most important single collections of British fossils in the world.

The Petrological collection contains more than 200,000 specimens, which is used for reference purposes. This collection is made up of a suite of smaller collections, which includes England & Wales sliced rocks, reference minerals, museum reserve collection, building stones and private collections. *Hollyer et al* (2000).

The NGRC (National Geological Records Centre) is a unique archive of national importance containing over three million items with information dating back over 200 years. Since its inception, the National Geological Records Centre has maintained, collated, and indexed large collections of geological data. The Data Centre is a recognised Place of Deposit for Public Records and is also the Natural Environment Research Council's Designated Data Centre for data generated by research in earth sciences. *Bowie* (2000).

The BGS Library at Keyworth, holds reference literature and documents to support bibliographical services both to staff (at home and overseas) and to members of the public. In over 150 years of existence, the collections have grown to become one of the world's major earth science libraries. Material is acquired by exchange as well as by purchase and in the past has been enhanced by incorporation of other collections, such as the extensive holdings of the former Overseas Geological Surveys which merged with the home survey in 1965.

The Library collections comprise the following types of material:

- photographic albums and prints (some 70 000 photographs in total)
- World Maps Register Index (map registers for the library's holdings for overseas areas)
- books, monographs, conference volumes (over 500 000 items)
- serials (some 3000 periodical titles currently taken)
- pamphlets, scientific papers, standards, theses
- archives of historical and national interest *BGS* (2004)

1.3.2 Edinburgh

This report relates to the Collections areas reported on in previous years, namely the Palaeontology and Mineral and Petrography stores and the Archive Room in Murchison House. In addition to these stores the Loanhead and Gilmerton Core Stores, the Library Store and computer Server Room have been added to the routine monitoring programme.

The Palaeontological collection comprises approximately half a million specimens in 3 main sub-collections from Scotland and northern England: the working, or Survey Collection, the Museum, or Type and Stratigraphical Collection and the Palaeontological Slide Collection.

The Collections are housed in linked but separate stores in a variety of trays ranging from museum standard cabinets to lidded and open wooden and plastic trays.

The Petrological collection contains more than 130,000 specimens. As with the Palaeontological collection this collection comprises a number of sub-collections, including the Scottish sliced rocks, S&N, the Murchison, the Edinburgh and the Systematic collections. All of these collections with the exception of the Edinburgh & Systematic collections have associated thin sections. There are also a small number of reference minerals, and a growing number of building stones samples. *Hollyer et al.* (2000). This collection is stored in two rooms, one containing cabinets for the thin section collection and one housing the remaining sub-collections.

These important Collections, both Palaeontological & Petrological, assist Survey field geologists in mapping projects and an increasing number of commercial activities; additionally external academic and commercial enquirers utilise the Collections in their studies. It is, therefore, important that the storage environment is as stable as possible in order that the integrity of the Collections is preserved.

The Archive Room contains archive data for permanent retention: contents include field maps and notebooks generated by BGS staff in the course of their work surveying the UK landmass. There are also BGS seismic data and offshore reports, mine abandonment plans and other donations from sources outwith the Survey. These records must be stored in conditions laid down in BS5454:2000.

The core stores are large warehouse-type buildings remote from the main office, between them they hold in the region of 300,000 boxes of sample material. It is known that the buildings are below standard for sample storage and there is no means to improve the environment. The data loggers are therefore set to record values at 30–minute intervals, downloaded every 4-weeks, to provide accurate documentation of the environment at these sites.

The computer suite Server Room and Library store have also been included this year, again on a monitoring brief only. The Server Room is fully air-conditioned and therefore, hopefully, is at the optimum environment for the equipment held in it: the Library store has no conditioning and limited heat.

Data from an external logger is also available; this provides a useful comparative dataset to those data acquired inside.

1.4 ENVIRONMENTAL MONITORS

Three different types of monitors are used to measure the temperature and humidity of the collections; a further two monitors measure external climatic variations.

The main logger is a combined temperature and humidity recorder, the Digitron Monolog2. This instrument records data at an operator set interval and is downloaded regularly to provide a complete record of the environment of an area.

The other types of instrument used are a Digital Memory Thermo-hygrometer and a Diplex Digital Temperature monitor.

2 Monitoring at Keyworth

At Keyworth, readings from seventeen monitors have been used to produce this report. In addition to the permanent monitors used during 2005, 2 monitors have been placed in SNS (Systems & Network Support) Server Room in J Block on 2nd May 2006. Whilst, an additional monitor has been located in 'Jurassic Towers' of N Block from the 9th August 2006.

It must be noted that the Museum Thermohygrograph was decommissioned at the end of May 2006. This is due to the red data plotter pens drying out, however, when black plotter pens were used, this stopped data from being recorded properly. It was decided not to replace this device, as there were 2 monologgers already present on the ground floor of the Museum, in addition they produced more accurate readings over a shorter time period. The Museum Thermohygrograph data therefore has been removed from this report.

The monologger that was placed in the weather station during spring 2005 was removed from this location on the 9th February, as this was providing spurious and inaccurate data, especially with regard to the humidity readings. This was thought to be due to night time condensation precipitating on the humidity sensor, which failed to evaporate off during the remainder of the day. This monitor was then placed in a wall cabinet on the ground floor of the museum containing sub-fossil bone. The weather station monologger data has been omitted from this report, and the thermometers in the Stevenson Screen have been used instead for external weather comparisons.

To summarise, new localities for this report include two monitors in SNS Server Room, one in Jurassic Towers and a monologger in a museum wall cabinet.

2.1 CALIBRATION DATA

All the environmental monitors used at Keyworth had been initially calibrated at different times during manufacture. It was decided that for the data to be consistent, they should all be re-calibrated at the same time. Sending the loggers back to the manufacturers for re-calibration would be too costly and so it was decided that they should be calibrated 'in house'.

2.1.1 Calibration Method

Over the period 27th February to 28th February 2006, all of the monologs were placed within an empty mahogany, glass fronted wall cabinet within the museum. This location was chosen, as it was large enough to house all of the monitors, including the thermohygrograph – even though it was decommissioned later on in the year. Please note, the monitors used for the SNS server room and Jurassic Towers have not been included during the calibration exercise, as these were put into operation later on in the year.

The advantage of using this location was that any fluctuations occurring in the museum would not be recorded within the cabinet, due to the excellent buffering properties of the mahogany wood and glass front construction.

The raw data collected during the calibration period was downloaded from the monologs and was tabulated into excel and graphed. (See Figure 1)

The layout of the graph is as follows; the temperature readings are recorded towards the bottom of the vertical axis with the ideal temperature ranges of 16-22°C indicated by solid black horizontal lines. The humidity readings are positioned above the temperature values; the ideal humidity ranges of 45-55% indicated in the same manner as the temperature. This layout applies to all the line graphs within this report.

Over the calibration period the temperature variation is marginal, with a slight increase towards the end of the experiment; however all the monitors are within the recommended range.

For the humidity readings, all of the monitors are below the minimum recommended range, with the cold store and museum wall cabinet (sub fossil bone) being the closest to 45%RH. All of the monitors are showing mostly consistent values during this calibration period.

This graph and associated data was then used to calibrate the loggers so that the values were more consistent with each other.

Using the four newest monitors, which should be the most accurate; the calibration factor was based on data from these, to provide a benchmark. Average temperature and humidity readings were obtained from these monitors over the calibration period and then applied to the remaining older monitors. This method should give us true values for all the locations without returning the monitors to the manufacturer for re-calibration. Table 3 summaries the calibration values.

Logger No	Logger Name	Av. Temperature	Adjustment	Av. Humidity	Adjustment
0112-096	Core Store Main Corridor	19.1	-0.4 C	28.4	+3.1%
0109-595	Core Store Extension	18.7	Nil	29.8	+1.7 %
0109-597	Pallet Store	18.5	+0.2 C	30.2	+1.3%
0112-066	Tray Store	18.7	Nil	29.5	+2.0 %
0407-204	Cold Store	18.4	+0.3 C	34.9	-3.4 %
0407-196	NGRC Box G239	18.6	+0.1 C	28.1	+3.4 %
0407-217	NGRC Aisle 67	18.7	Nil	30.4	+1.1 %
0407-219	NGRC Strong Room	18.7	Nil	30.5	+1.0 %
0407-210	Museum 1st Floor	18.6	+0.1 C	27.5	+4.0 %
0407-213	Museum Ground Floor	18.6	+0.1 C	31.1	+0.4 %
Average calibration temperature & humidity based on the 4 newest monitors during the calibration period					
0429-015	Conservation Laboratory				
0429-018	Inside Museum wall cabinet - Sub-fossil bone				
0429-033	Library Strong Room				
0429-037	Museum Cabinet 1st floor	18.7		31.5	

Table 3: Summary of Calibration Data – Keyworth

The data for this calibration period was automatically adjusted using a macro in Microsoft Excel. This newly ‘amended’ data was then re-graphed to show all of the monitors after the calibration factor had been applied. (See Figure 2). This now shows that all of the monitors for both temperature and humidity are calibrated together with little or no variations between them.

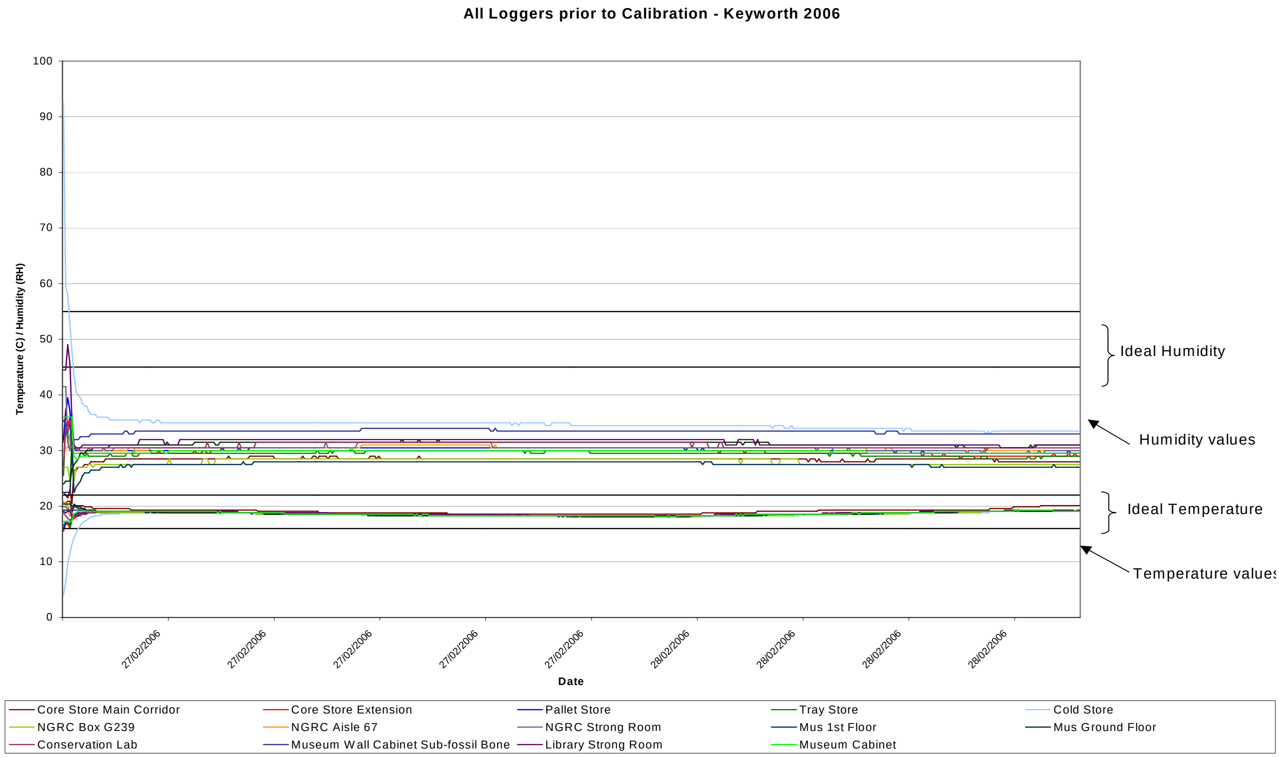

Figure 1: All Loggers prior to Calibration Period - Keyworth 2006

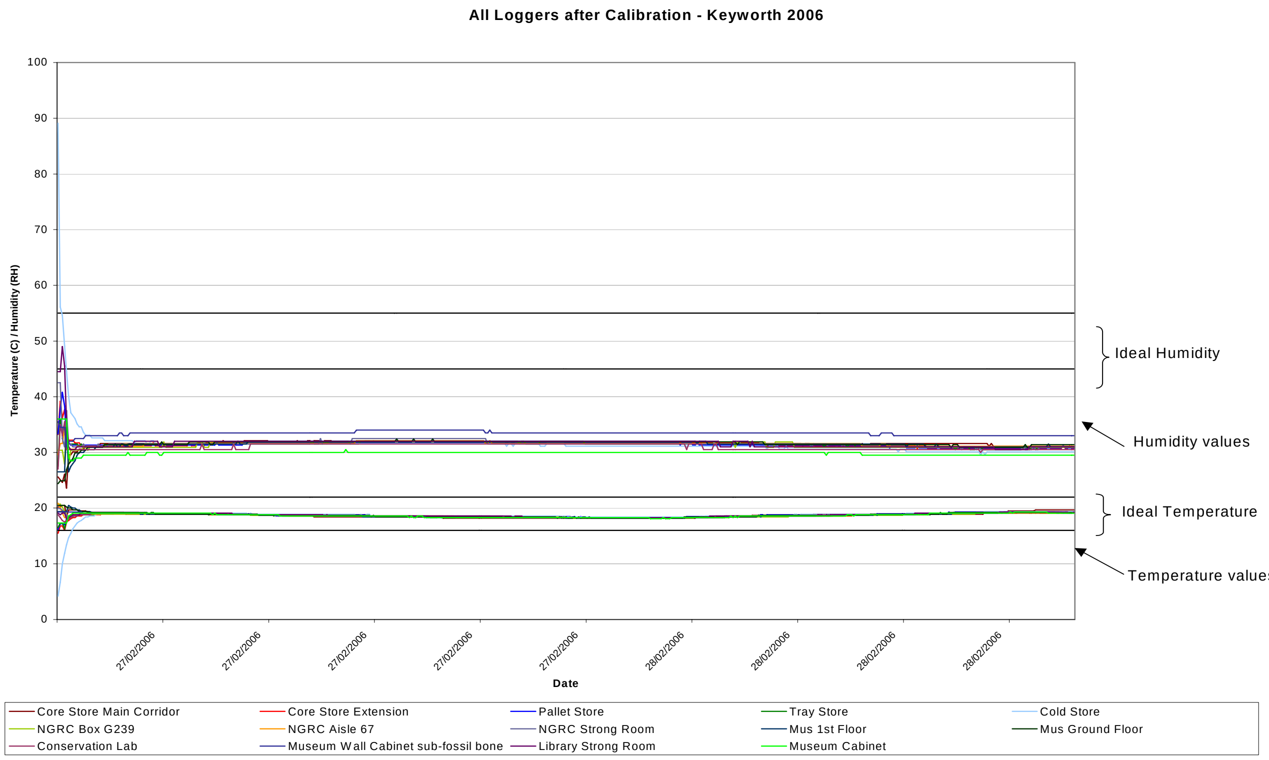

Figure 2: All Loggers after Calibration Period - Keyworth 2006

2.1.2 Calibration Summary

From the calibration period this year, variations in temperature and humidity were seen to still exist between the monitors, especially ones of the same types, even though they were situated in the same location. The adjustments made this year were small, and these alterations are comparable to those made to the data used for last years report.

This indicates why the environmental monitors should be re-calibrated on a regular basis. And then allows us to obtain a more accurate understanding of the climatic changes within the storage areas. More accurate comparisons can then be made between the different storage areas in the same time period.

The 'in-house' calibration method used at Keyworth whilst not being as accurate as re-calibrations carried out by the manufacturer, was felt to be justified as the savings made by in-house calibration could be used to purchase additional monitors and thus we could monitor additional areas within the collections.

2.2 DATA EXTRACTION

The data for this report was downloaded from the monologgers in their original format and saved in the form of .lcf files. This file extension is used to view the data with the relevant loggers software. This data was then converted into a .csv file format to enable the import into Microsoft Excel. Weather readings from the weather station were entered directly into Excel.

The raw data from the monologgers was downloaded into a GMT format via a laptop computer.

All the data was calibrated where necessary, using a calibration macro in Excel. From this the data was filtered using Excel to show readings to the nearest 30 minutes or in the case of the weather station every 24 hours.

This data was then used to generate the graphs in Excel.

Please note: all data for this report can be found on a disk attached to this report.

The layout of the data will be in the following format:

- All raw unformatted data (lcf format) will be presented in folders for each type of monitor. Raw data will be presented in a .csv format (readable by MS Excel).
- Data used for calibration purposes will be in a sub folder.
- The thirty minute extracted, calibrated data used for yearly graphs, will be presented in folders. The yearly histogram data is also included.

2.3 YEARLY CALIBRATED RESULTS MUSEUM & CORE STORE 2006

The main objective for Keyworth is to routinely monitor temperature and humidity; within the storage areas of the collections. This has been ongoing for the last five years.

Four monologgers are operational within the museum; two of them are being used for general comparisons between each floor, whilst the other two are used within specific areas of the museum. (i.e. sub-fossil bone & museum cabinets).

The Thermohygrograph located on the ground floor of the museum has been decommissioned. Because of the red plotter pens drying out, and the black pens that were used instead resulted in inaccurate readings being produced. It was decided that the two monitors on the ground floor would be sufficient at providing more accurate and regular readings compared to the hygrograph.

The monologger that was placed within the weather station during March 2005, was removed as it was providing inaccurate readings due to excessive water vapour condensing on the sensor.

The thermometers in the weather station were then used to record the meteorological readings every 24 hours. This monitor was then relocated to the ground floor of the museum in a glass wall cabinet containing sub-fossil bone. This would provide additional readings on the ground floor of the museum, now that the thermohygrograph is no longer operational. Comparisons could then also be made on the buffering effects of the glass cabinets on the sub-fossil bone material.

All of these monologgers are recording data at three-minute intervals.

Three monologgers are situated within the Core Store, they are located within the pallet store, core store extension and tray store.

The pallet store logger is positioned in the second aisle, about a third of the way down, two metres above the ground.

Within the core store extension, a logger has been placed 4.5 metres from the end of the first fully filled rack.

Whilst within the tray store a logger is positioned on the top floor, 77cms above that floor level and adjacent to the main open area of the core store, which is approximately 7.5 metres below.

This chapter (2.3) will discuss the results obtained during 2006 and will also make comparisons with the annual readings from 2005. Monitors positioned in other areas within the collections will be presented and discussed in subsequent chapters, as it was decided that to include all the results together would make the graphs too complex to discuss the data properly. This includes the new locations monitored within the museum wall cabinet, SNS server room and Jurassic Towers.

In previous years, the yearly-calibrated results have included existing environmental monitors from both the core store and museum. It was decided that this data and its subsequent discussion was becoming too complex to summarise. Therefore this year, the main areas have been split into the museum and core store respectively. This should provide the reader with a better understanding of the data-sets being shown.

2.3.1 Yearly results within the Museum: Discussion

An annual graph for 2006 has been produced for the two main loggers on either floor of the museum during 2006, (Figure 3), with external climatic readings and averages graphed in Figure 5. For comparative purposes, 2005 museum data is shown in Figure 4. These graphs show the trends throughout the year plus any changes in temperature and relative humidity. A monitor is situated on the first floor of the museum on a display bench, on the south-east side of the building. Whilst, the ground floor monitor is positioned on top of the glass wall cabinet; on the south-west side of the building.

The results for the museum on both floors show similar temperature readings; almost identical, throughout the year for both 2006 and 2005. However, there is a slight difference between both floors during different months in the year; this is more noticeable throughout 2006. Slightly lower temperature readings occur on the first floor of the museum; during the end of January to the beginning of March. This could be because the ground floor monitor is situated at a higher level than the first floor monitor, and the effect due to warm air rising from the central heating. Whilst the higher readings produced by the first floor monitor during the summer months, may be due to when the sun is stronger, and possibly heating up the building, even though the window blinds remain shut in the museum at all times.

For the majority of the time, throughout the year; the temperature is within the recommended 16-22^{o}C, except for particular times during the summer when the outside temperature (Figure 5), was probably one of the hottest recorded by the Met Office and University of East Anglia (UEA) in Central England since records began. *BBC, 2006.*

During the colder winter months (January – March, & December), the outside temperature was struggling to reach 5^{o}C, however, both floors of the museum showed a comfortable 18^{o}C on average, regularly within the recommended 16-22^{o}C. This was mainly due to the central heating being operational during those periods. The graphs even recorded the weekly patterns when the heating is turned off during the weekends. Facilities Management claim that this is a more economical way of heating the site, rather than keeping it ticking-over when the site is shut. If the heating was left on all the time, this would possibly remove the weekly temperature cycles, and would perhaps reduce the fluctuations and produce more stability in the humidity readings.

Elevated temperature readings were recorded during the late autumn (mid October–mid November), this was due to the museum air circulation system not being operational, and one of the warmest ever autumn's on record. *BBC, 2006.* Coupled with that, the central heating was also functioning across the site during this time. Facilities Management was informed about the excessive temperatures (reaching 26^{o}C) in the museum, and the air circulation system was reactivated, which allowed the temperature readings to return to a more acceptable level within the 16-22^{o}C range.

The humidity readings however are below recommended parameters at the beginning of the year, similar to those recorded during 2005. These trends appear to follow a similar pattern to the external humidity (Figure 5), i.e. from January to mid February, and March to April, but at decreased levels, due to the fabric of the building protecting the internal environment and the central heating being operational through the spring.

When the heating goes off across the site from mid April and external temperatures start to gradually increase, then humidity levels also begin to rise. A similar pattern occurred in 2005 but commenced from mid May.

During 2006, the humidity is within the recommended 45-55%RH more often from late spring through to mid summer, whilst the humidity values in late summer (August-September) only touch the maximum recommended range on a few occasions.

The humidity values internally follow a similar pattern to the external humidity during the summer months; this is particularly noticeable around the beginning of June, mid July and the beginning of August. At the end of summer and into autumn, the humidity levels are still high due to a unusually warm period being recorded. At the beginning of November the humidity drops from being above the recommended parameters to within the 45-55% RH. This decline in humidity is similar to 2005 during the same period. However, the values recorded during the winter of 2006 are much closer to the 45-55%RH compared to 2005.

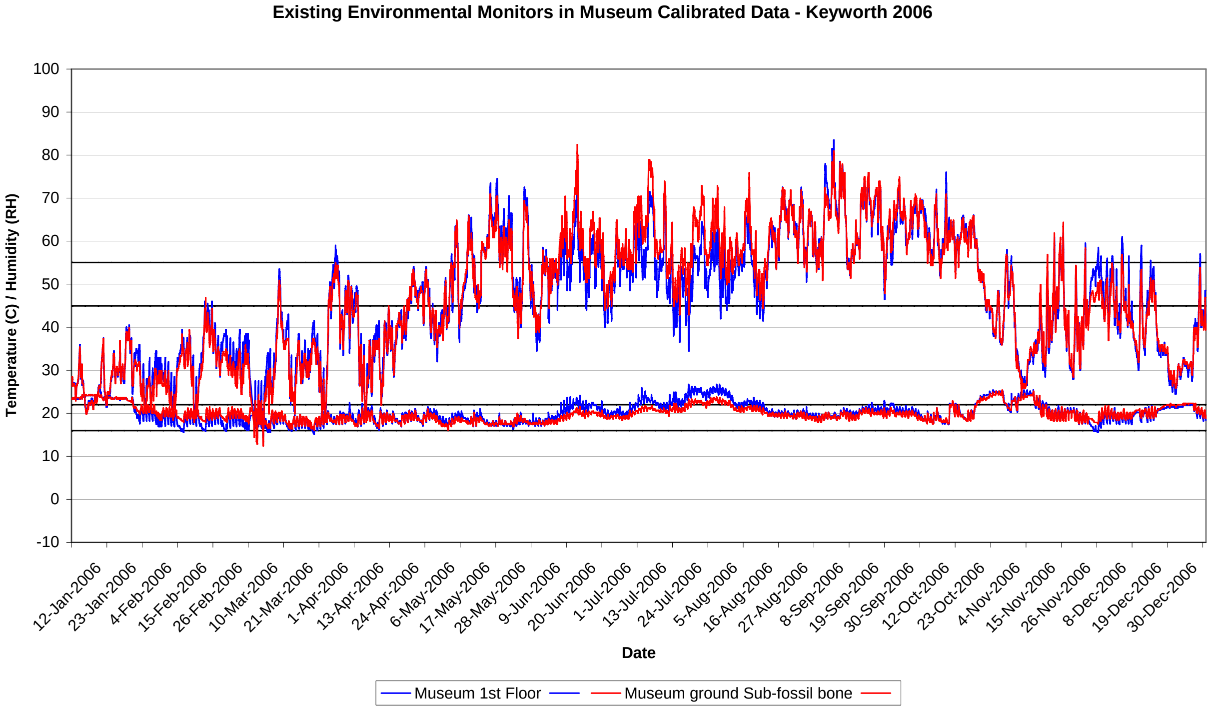

Figure 3: Yearly readings for Monitors in the Museum - Keyworth 2006

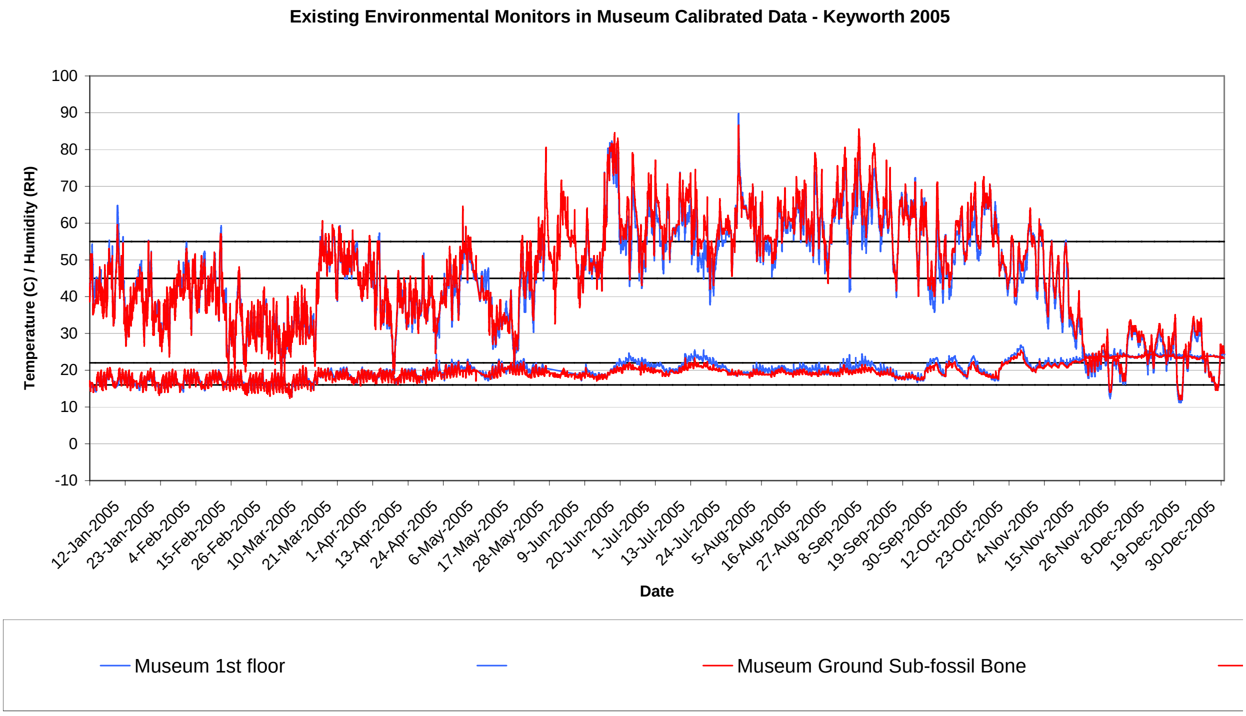

Figure 4: Yearly readings for Monitors in the Museum - Keyworth 2005

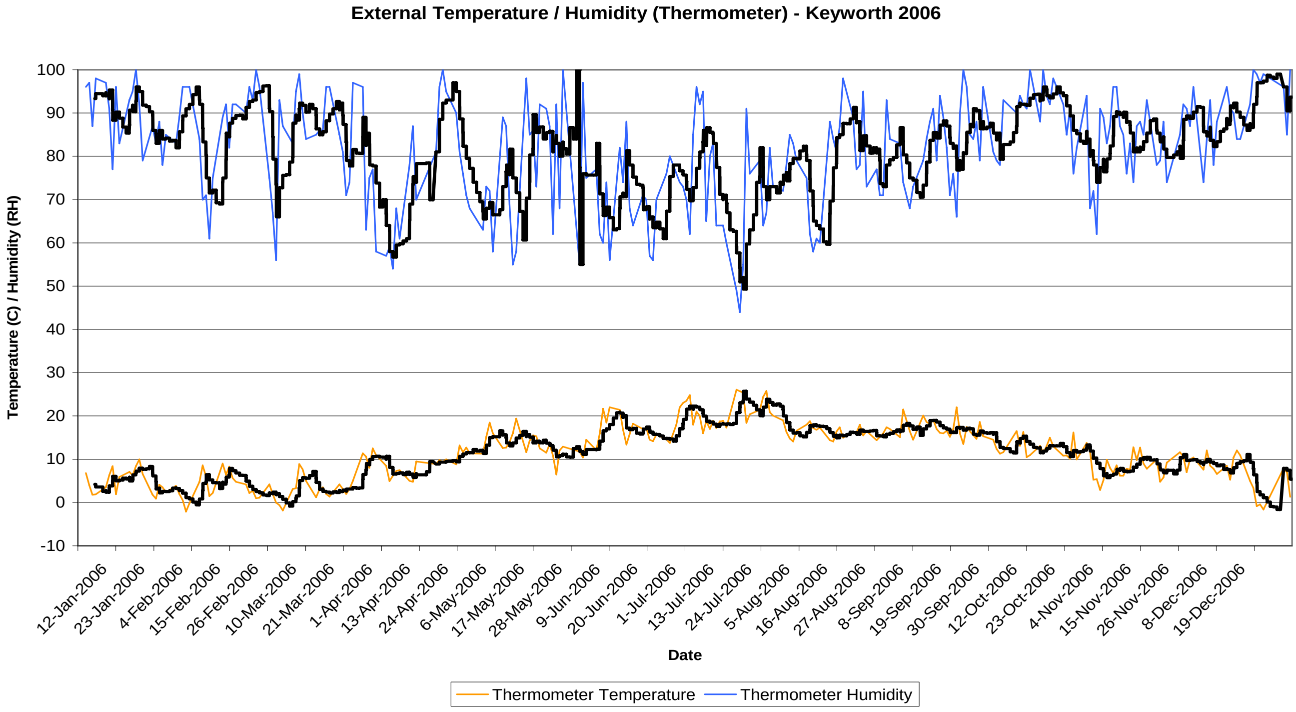

Figure 5: External Temperature and Humidity - Keyworth 2006

2.3.1.1 DISCUSSION OF YEARLY RESULTS IN THE MUSEUM THROUGH HISTOGRAMS

Histograms have been produced, to assist the reader in viewing the results. It is hoped this will provide a complementary picture to the line graphs, without 30-minute readings being displayed. These graphs are shown as a percentage; for the amount of time each monitor falls within, above or below the recommended parameters for temperature and humidity throughout the year.

Figure 6 and Figure 7 show the temperature ranges for the museum monitors in 2006 and 2005 respectively, whilst Figure 8 and Figure 9 show the comparisons of humidity readings during 2006 and 2005 respectively.

Comparing the temperature readings recorded on both floors of the museum; 2006 has seen an increase within the 16-22^{o}C range by 9% compared to 2005, with values equating to over 70% of the time spent within these parameters. As there has been an increase in readings falling within the recommended range, there has been a decrease in percentage of time outside these recommended parameters compared to 2005. The largest decrease is for the number readings below 16^{o}C threshold on both floors of the museum, whilst there has also been a decrease in the number of readings above 22^{o}C. These findings are encouraging considering the high external temperatures experienced during 2006.

The humidity histograms look very similar for both years, but there has been a slight increase in the number of values that fall within the 45-55% RH guidelines for the ground floor monitor compared to 2005. The first floor monitor has shown a slight decrease of readings within this range. There has been a decrease in the time spent below 45% RH for both floors, whilst a slight increase for the percentage of time spent above 55%RH.

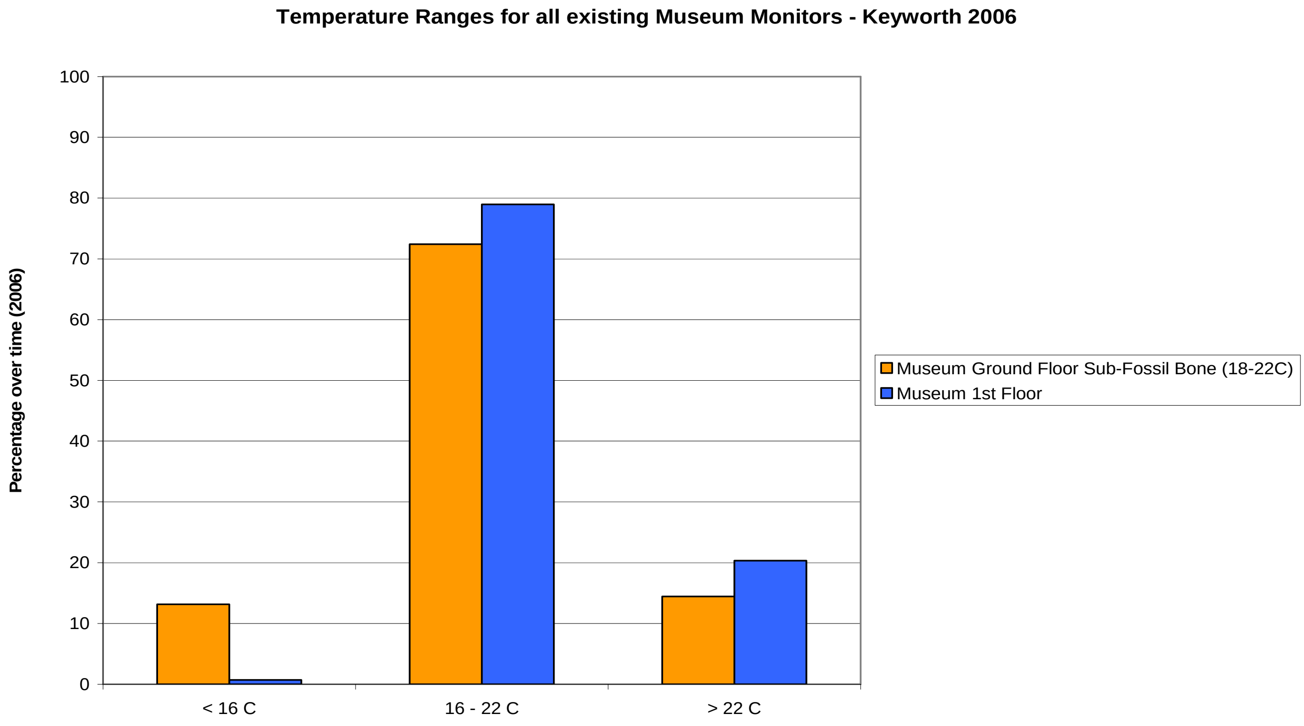

Figure 6: Histogram: Temperature ranges for monitors in museum – Keyworth 2006

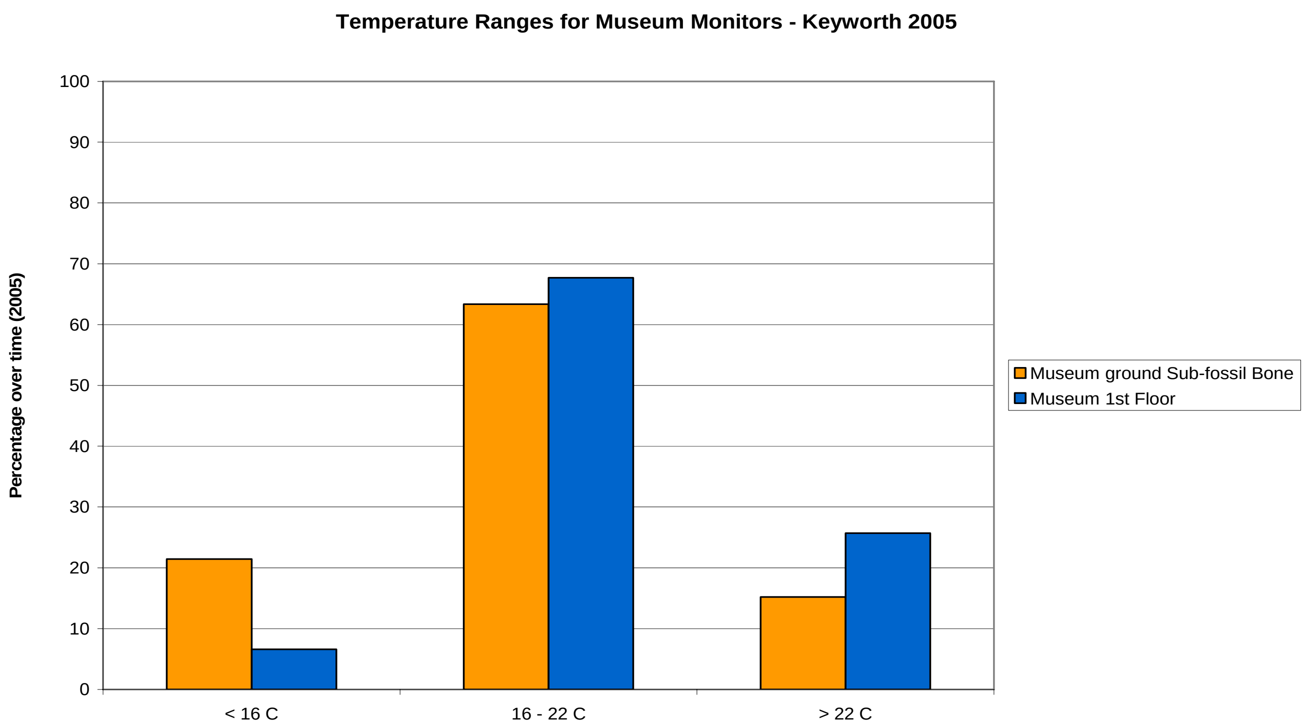

Figure 7: Histogram: Temperature ranges for monitors in museum – Keyworth 2005

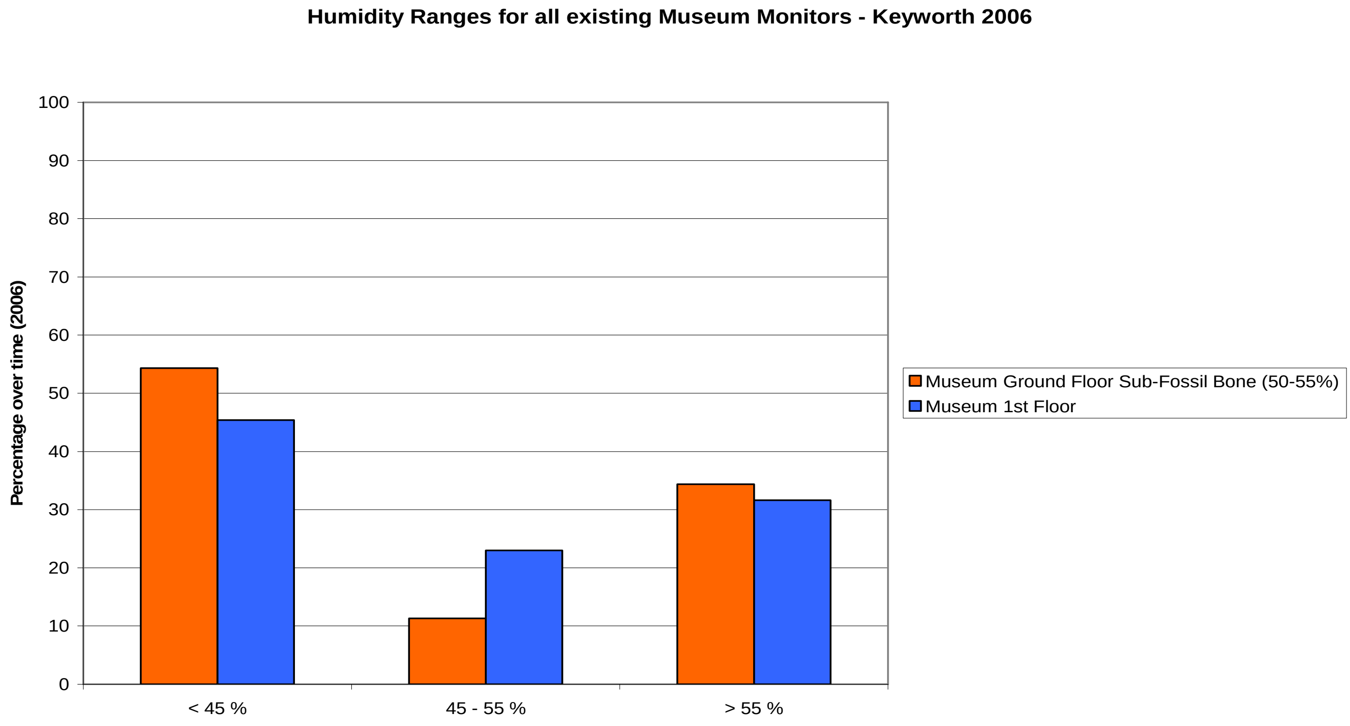

Figure 8:Histogram: Humidity ranges for monitors in the museum – Keyworth 2006

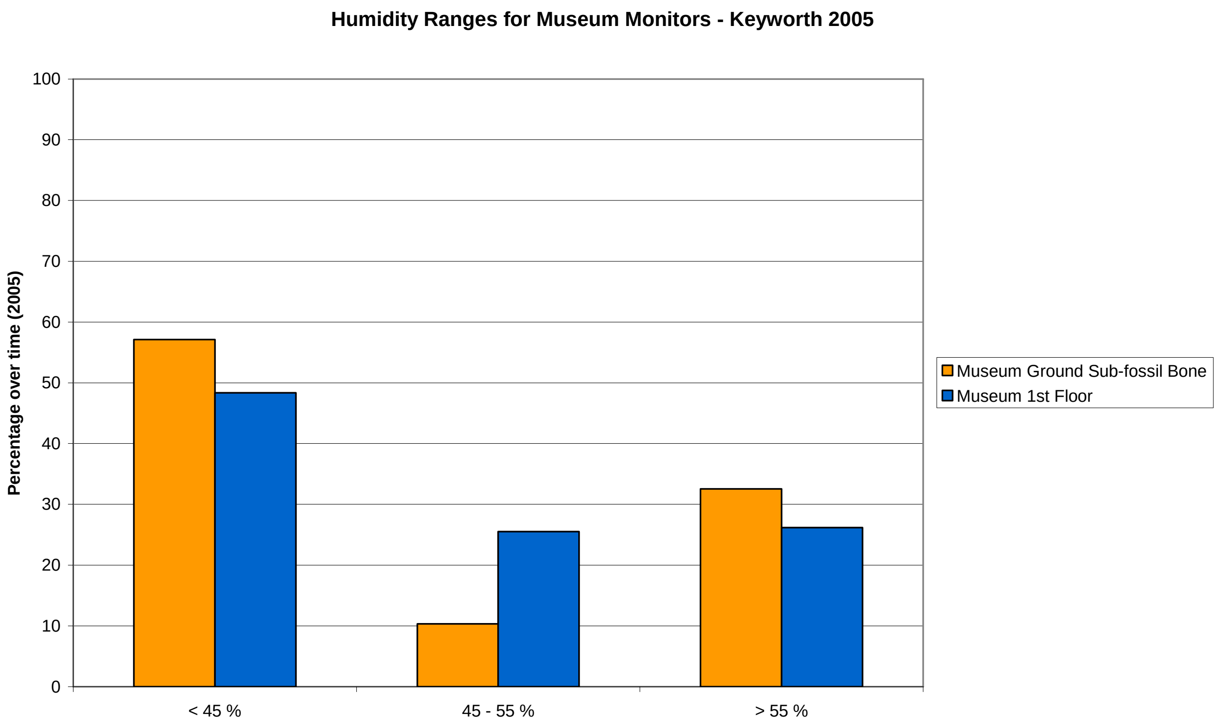

Figure 9: Histogram: Humidity ranges for monitors in the museum – Keyworth 2005

2.3.2 Yearly results within the Core Store: Discussion

The data for 2006 has been graphed for all the main loggers in the core store; these include the Pallet Store, Core Store Extension and the Tray Store, (See Figure 10), whilst comparative data from 2005 is shown on Figure 11. Weather readings for 2006 are shown in Figure 5. Additional monitors used in other areas of the core store are discussed in subsequent chapters within this report.

All three areas within the core store follow a similar pattern with temperature readings through out the whole year. For the majority of the time, recordings from all the monitors fall within the 16-22^{o}C guidelines except for during the summer months. This appears to be an improvement on 2005.

During the winter months and into early spring (January-April), temperatures in these areas are fairly constant, except for the core store extension; where on numerous occasions the temperature drops; reflecting external weather readings. This occurs during the end of January until mid February, with values nearer 8-13^{o}C. Similar occurrences are noticed throughout March and April. This coincides to when shutter doors are open at the rear of the core store for deliveries in this case from Rookhope Borehole. This therefore affects the temperature of the corridor and core store extension. Similar ‘drop-outs’ in temperature are also visible during July and November 2005, when the installation of additional racking in the core store extension and the delivery of samples from Penzance occurred, respectively.

Throughout summer, temperature readings increased. This corresponds with external temperatures rising, similar to 2005, however these rises are more pronounced in 2006 due to this being one of the hottest summers on record, *BBC, 2006*, during the summer temperatures reached 30.4^{o}C in the tray store. From late August through to September, temperatures stabilized and are similar to those in 2005; however the differences in temperature readings at each locality are more pronounced.

From November to December, all the monitors are falling to just within the 16-22^{o}C, with the tray store monitor occasionally being just above 22^{o}C. Each area follows a similar pattern especially when the core store shutter doors are open, thus allowing colder air into the core store. This is still noticeable during the early and latter parts of November and mid December, even though the central heating is on across the site.

Throughout 2006, the tray store was recording the highest temperatures. This is exaggerated during the summer, when the hottest temperatures occurred. This is not surprising, as the monitor for the tray store is situated on the top floor, and is directly below the metal roof of the building. Therefore as the Sun heats the surface of the roof, this causes the air underneath the roof to heat up within the tray store; even though air extraction fans and air circulation units are operational. It is also worth remembering that as hot air rises, is also likely to result in a rise in temperature in this part of the core store.

When you compare the tray store readings for 2005, this area also recorded the highest readings for all three locations; even though the summer values were more in line with the other areas. Whilst, the core store extension recorded the lowest readings throughout 2006, similar to those of 2005.

From the 2006 graph (Figure 10), the tray store showed the lowest humidity readings, whilst in 2005; this was one of the areas with the highest humidity. Whereas, the core store extension showed the highest humidity readings in 2006, but these were not the highest in 2005.

During January to March, there has been a visible improvement in humidity readings compared to 2005, even though for the most part they do not reach the minimum 45%RH requirement. These increases in humidity appear to be related to external conditions. This coincides with when the core store shutter door is open for deliveries.

Towards the beginning of April, there is a sudden increase in the humidity recorded for all three areas, this also occurred in March 2005. A number of possibilities for this could be, the central heating being turned off across the site, and therefore the air is not being dried; or another factor could be due to a dramatic drop in humidity externally during a period of increased temperature; caused by a warmer period of dry weather.

From April to the beginning of October, the humidity readings stay constantly within the 45-55% range for longer than 2005, despite the high summer temperatures and the associated high humidity. A similar pattern during the winter months occurs for both 2006 and 2005, where there is a decrease in humidity. This coincides once again, with the central heating being operational.

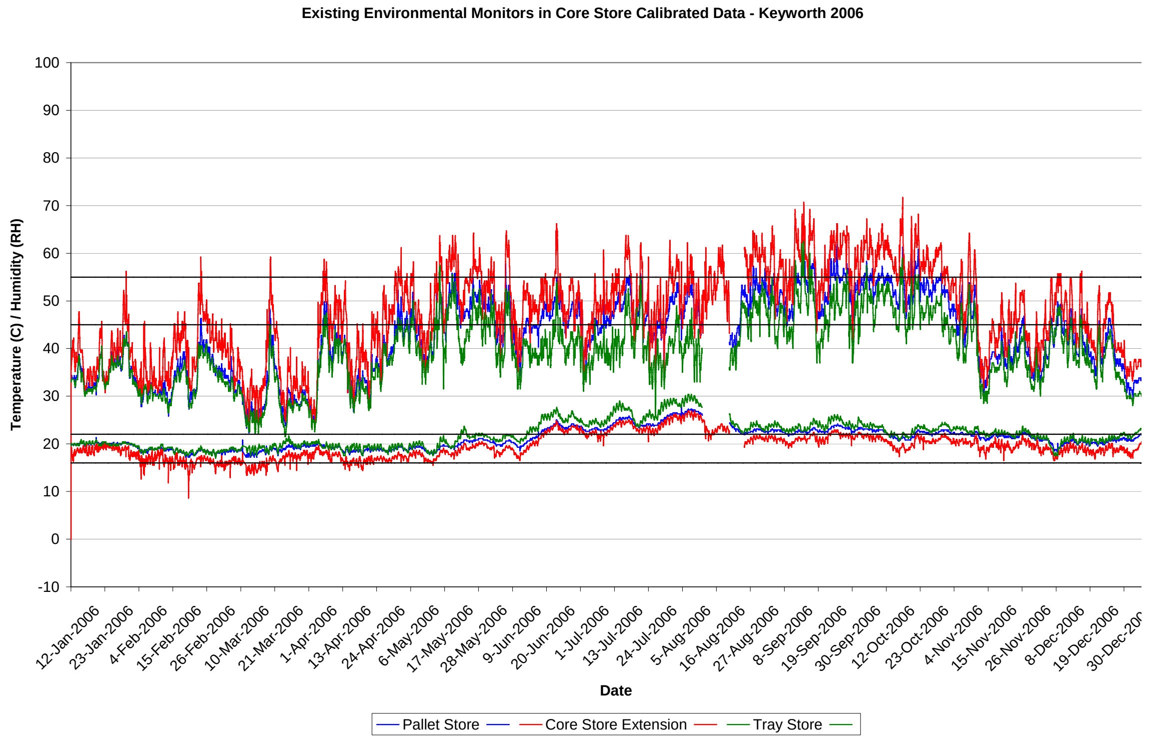

Figure 10: Yearly readings for Existing Environmental Monitors in the Core Store – Keyworth 2006

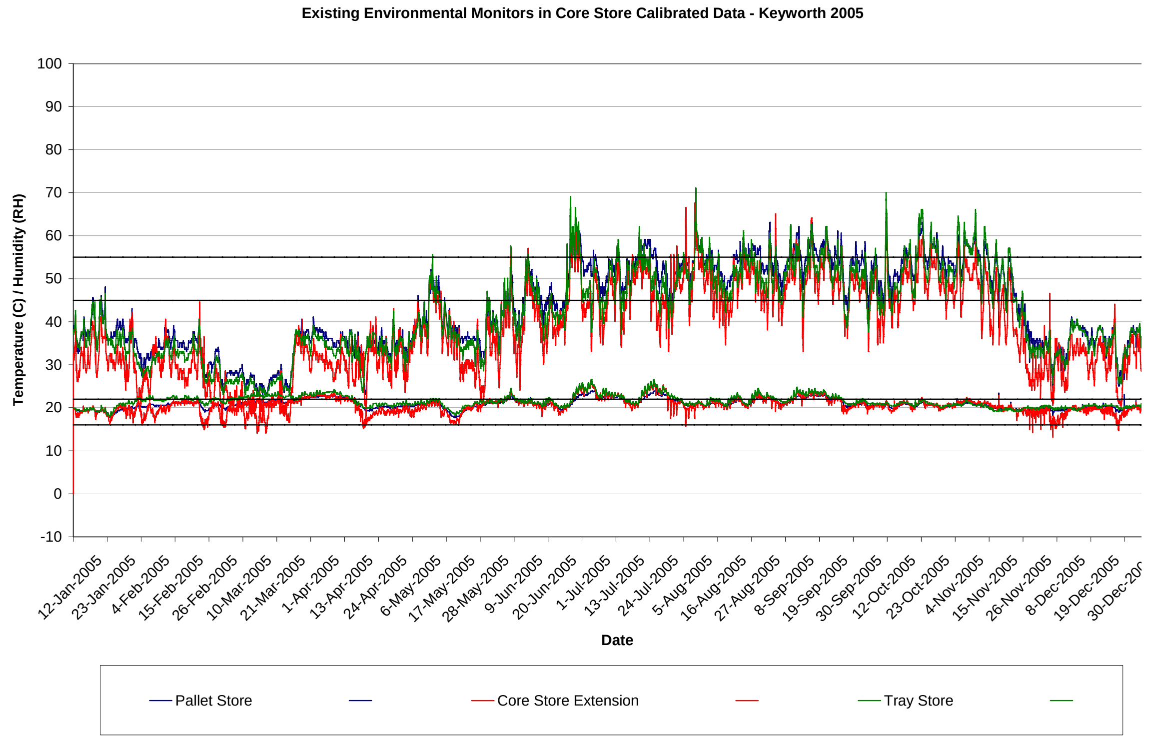

Figure 11: Yearly readings for Existing Environmental Monitors in the Core Store - Keyworth 2005

2.3.2.1 DISCUSSION OF YEARLY RESULTS IN THE CORE STORE THROUGH HISTOGRAMS

Histograms for the main areas of the core store in 2006 can be found in Figure 12 and Figure 14, whilst for 2005 these are in Figure 13 and Figure 15.

During 2006 there has been a general decrease in the percentage of time within the 16-22^{o}C range, for all areas within the core store. The most noticeable change belonging to the pallet store, with a 20% reduction in 2006, down to 60% of the time; whilst the least amount of change was the core store extension only showing a 3.9% reduction compared to 2005. Two possible factors that could have led to this decrease are, the increase in external temperatures and that a week worth of data was corrupt for these localities, so therefore this affects the percentage of time recorded. With a decrease in the 16-22^{o}C range, this has led to an increase outside of these parameters. These have mainly occurred in the greater than 22^{o}C range. Both the pallet store and tray store have seen an increase of 20.8% and 12.8% respectively. This is not surprising considering the hot extended summer we have experienced this year, together with the milder autumn/winter, which has pushed up the average external temperatures. The core store extension monitor has seen a decrease in the values above 22^{o}C, with a drop of 0.7%, however there has been an increase of 4.4% in this area with values below 16^{o}C. This is mainly due to the shutter doors in the core store being open during the year to allow for deliveries of samples.

Humidity readings in the core store have seen an increase within the acceptable 45-55%RH range by about 9% compared to 2005, where values were around 38% of the time. The pallet store and tray store have seen an increase in the percentage of time below the 45% threshold to values around 58% and 76% compared to 55% and 58% in 2005. The core store extension has seen a decrease within the 45-55% range by 28%, accounting for only 39% of time where humidity is at the optimum levels. This is due to periods of time where the shutter door has been opened, thus pulling drier colder air from outside, together with the central heating system drying out the air within the core store. For the percentage of time where areas are above 55%RH there has been a decrease in all locations except for the core store extension, which has seen an increase of 18%.

It can be seen that the opening of the core store shutter door has had an effect on both temperature and humidity within close proximity of the door. It is difficult to summarise if the opening of the door improves the conditions within the store. It depends on when the door was opened during the day and for how long, if the internal heating that was operational and effect of any external climatic conditions. Changing the conditions of the environment suddenly is not recommended and to be avoided when storing any geological collections. However we must remember that the majority of the collections are stored within sealed trays or boxes, and this hopefully reduces the effects of these changes in the environment.

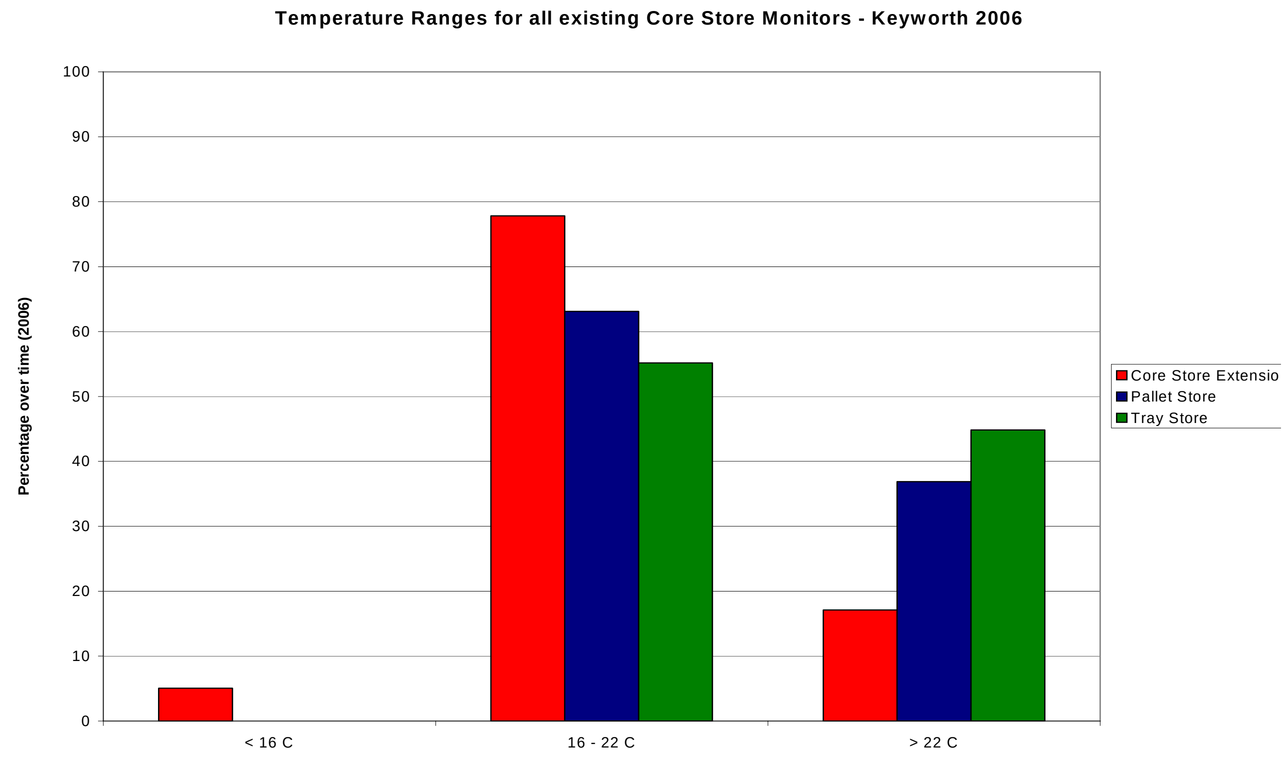

Figure 12: Histogram: Temperature ranges for Core Store Monitors - Keyworth 2006

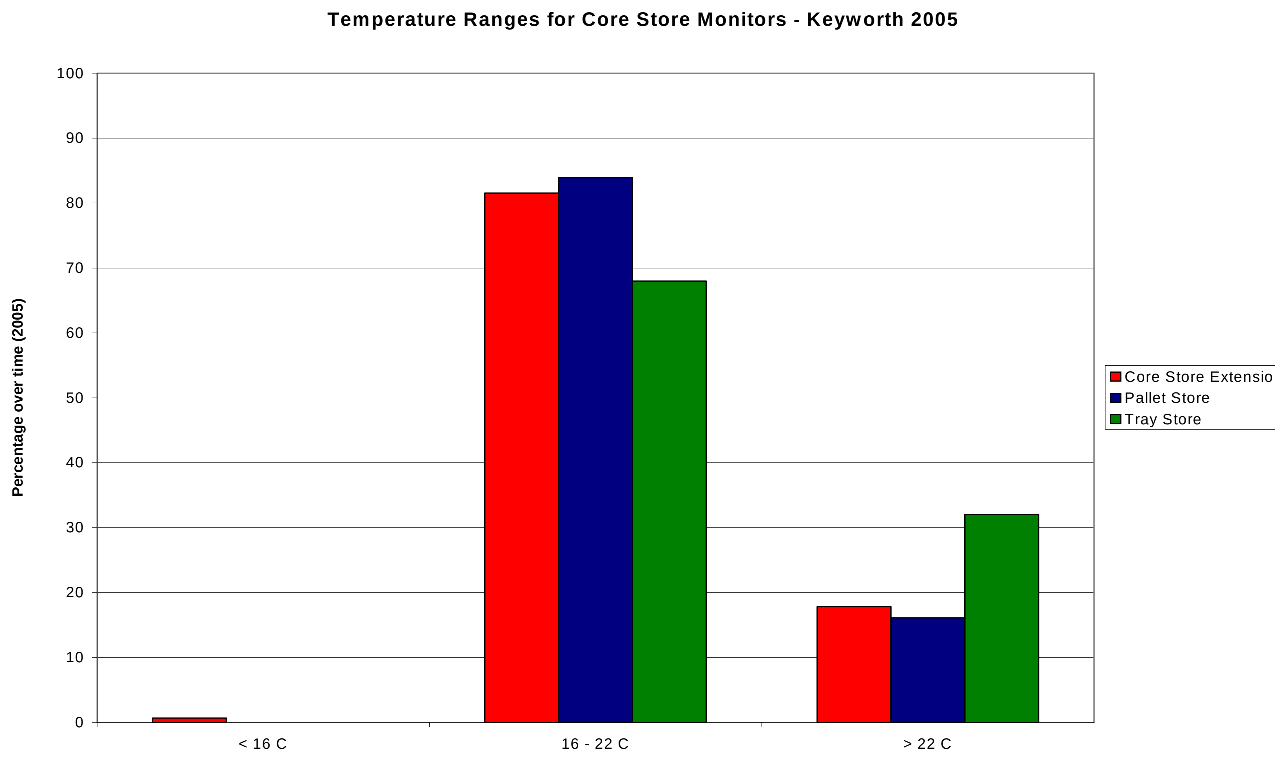

Figure 13: Histogram: Temperature ranges for Core Store Monitors - Keyworth 2005

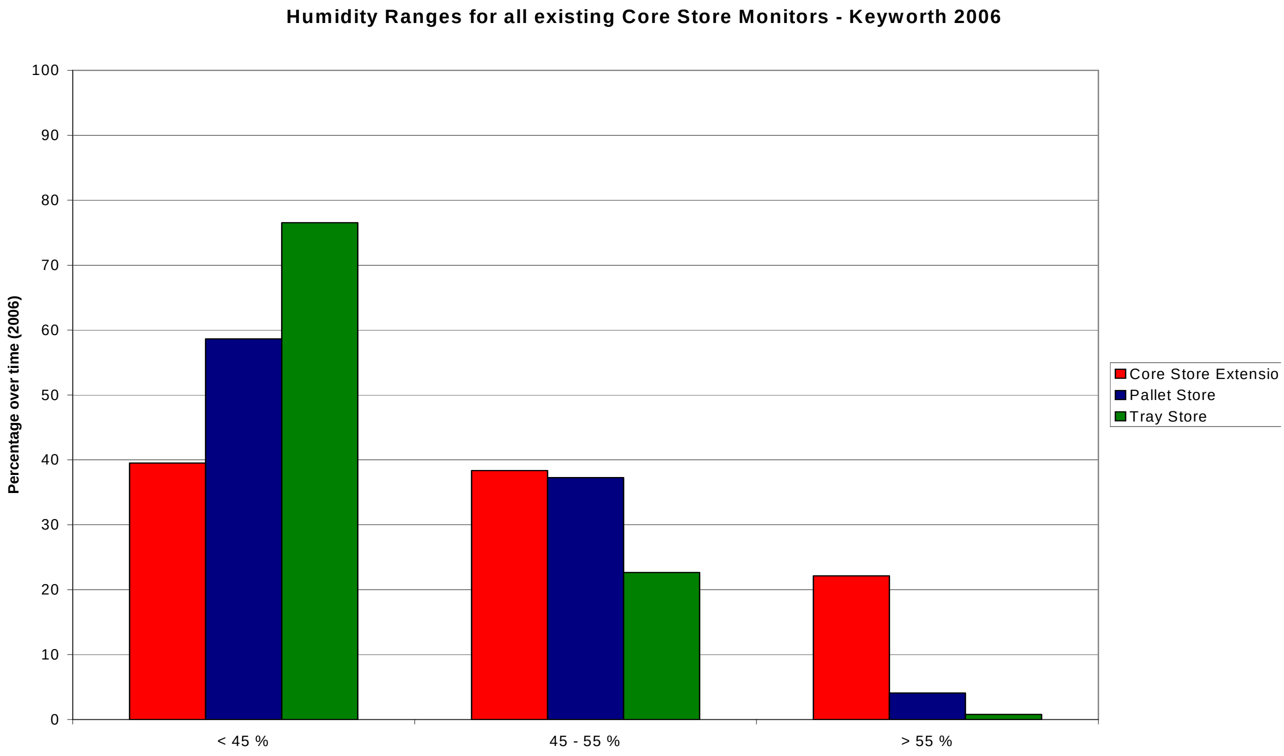

Figure 14: Histogram: Humidity ranges for Core Store Monitors - Keyworth 2006

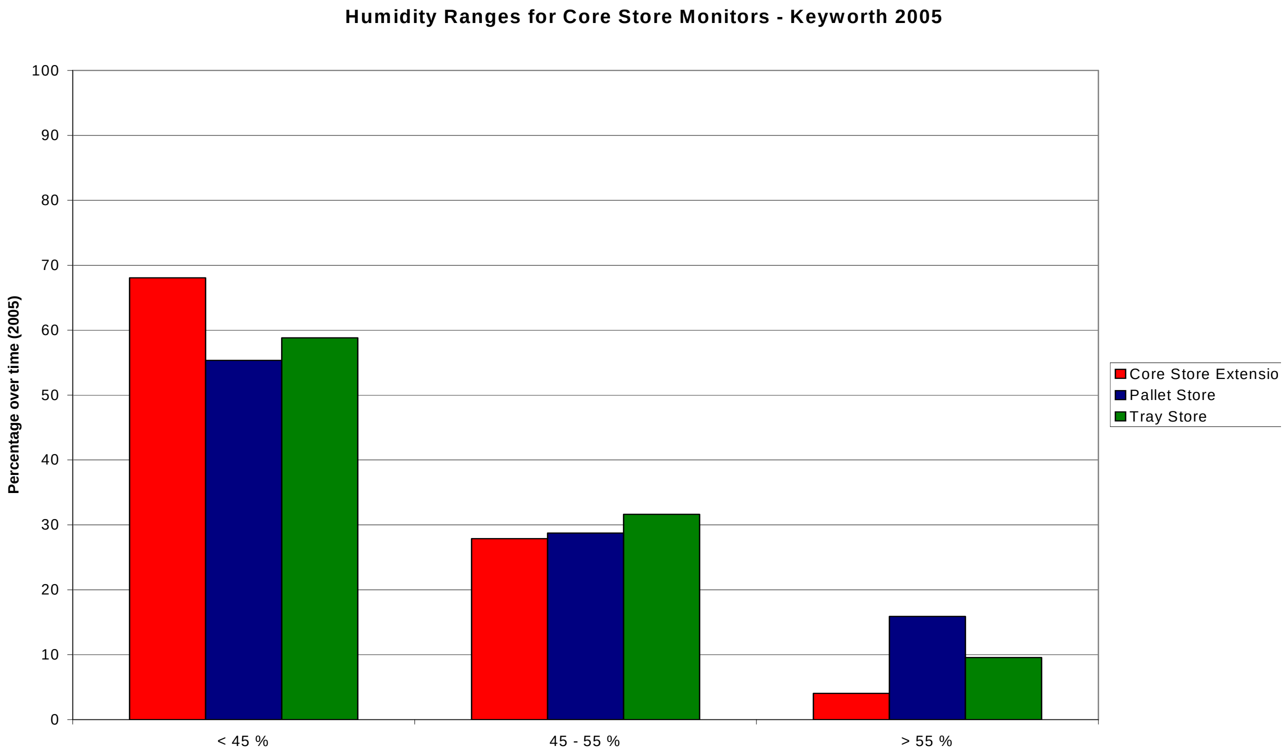

Figure 15: Histogram: Humidity ranges for Core Store Monitors - Keyworth 2005

2.4 ADDITIONAL MONITORS WITHIN THE CORE STORE AREAS 2006

Background information on these existing areas and monitors can be found in the report *Shepherd & Tulloch 2004*, section 2.4.

2.4.1 Conservation Laboratory & Core Store Main Corridor

Based on last year's trial experiment using a beaker filled with water, it was decided to re-run this technique to try and increase the humidity within the conservation laboratory. This commenced on the 1st February until 15th May 2007.

It must be noted that there is no data for the core store main corridor between 30th January and the 9th February as the humidity sensor in the monologger was faulty, this has since been rectified. Therefore, this data has been removed from the report.

2.4.1.1 CONSERVATION LABORATORY & CORE STORE MAIN CORRIDOR RESULTS

Annual graphs for 2006 and 2005 are shown on Figure 16 and Figure 17.

Temperature readings from January through to May follow a similar weekly pattern, which coincides when the heating is on during the winter months. This is not as pronounced as during 2005, but is still noticeable. More time is spent with readings falling within the 16-22°C range, with the conservation laboratory showing slightly elevated readings throughout this period.

In the summer months temperatures rise above 22°C, however the core store main corridor readings are more stable than in 2005. Both areas show the effects of the high external temperatures, even with the corridor monitor being in a larger area with better airflow than the laboratory.

For the remainder of 2006, there is an improvement in conditions compared to 2005, with more stable readings occurring within the 16-22°C range. Whilst the weekly cycle of the central heating being operational is still noticeable during the winter compared to 2005, but to a lesser extent.

The effects of the core store shutter door being open, during February-March, have had an impact on the readings from the core store corridor and conservation laboratory. I'm not surprised that this has affected the corridor monitor, but the effects on the conservation laboratory are more unexpected. The cause is likely to be due to a ventilation grill being present in the conservation laboratory door. This is a requirement to allow enough airflow for the fume cupboard, which is situated in the laboratory. When the fume cupboard is operational, air is drawn from outside; i.e. the core store corridor. Even when it is not in use, there is still some airflow into the laboratory. Without sufficient airflow an alarm would trigger in the fume cupboard which would then cause it to shut down. Another factor may be that the conservation laboratory does not have its own radiators, as the room has become too hot in the past, but just contains lagged transitional heating pipe work to other areas of the core store.

These results reinforce the recommendation, that the use of the shutter doors should be kept to a minimum where feasibly possible, so as not to effect the environment of the surrounding areas.

During the spring, the humidity levels have improved compared to 2005, with measurements being closer to the minimum 45%RH recommendation.

Even with the humidity beaker experiment running (February-May), it is difficult to say if the experiment is helping to boost the humidity within the laboratory, as the core store corridor is showing almost identical values. If the conservation laboratory was a sealed room, it would show far more accurate results, but with the ventilation grill on the door drawing air through from the corridor, particularly when the shutter doors are open at the rear of the core store, it is difficult to separate out the effects.

Throughout the summer there is an increase in humidity levels for both areas, with the conservation laboratory showing slightly higher readings, possibly because the laboratory is an enclosed room rather than an open space. The increase in humidity readings is similar to those of the core store main areas (Figure 10), however there is a delay with which these humidity readings start to increase. This may be due to the positioning of these monitors in relation to exits and windows etc.

During the winter months both the core store corridor and conservation laboratory follow a similar pattern to the core store extension, but at slightly lower levels below the 45%RH threshold.

The humidity pattern is identical to external humidity levels, which confirms that the core store corridor is being affected, especially when the shutter doors are open. This then has a knock-on effect for the monitor within the conservation laboratory, caused the increased airflow through the ventilation grill in the door to the fume cupboard.

2.4.1.2 Discussion for the Conservation Laboratory & Core Store Main Corridor through Histograms

From the histograms, the quantity of temperature readings falling within the parameters during 2006 has increased (Figure 18), compared to the previous year (Figure 19). Both the conservation laboratory and the main corridor have seen an increase in the percentage of time spent within 16-22^{o}C, now showing values of 66% and 57% respectively. This is an increase of at least 20%. Similarly, there has been a decrease in the number of values over 22^{o}C. Once again the numbers of readings above 22^{o}C are not as high as in the core store extension, due to the proximity of the monitor to the core store shutter doors, which are often opened.

For the humidity readings (Figure 20 & Figure 21), there is not as much improvement, to the time spent within the 45-55%RH range, increasing by 6% from the previous year for the conservation laboratory. Values below 45%RH have not shown any major changes. There is only a slight improvement for the conservation laboratory, but remaining around the 60% mark. Whilst readings greater than 55%RH, the core store main corridor has seen an increase of only 2%.

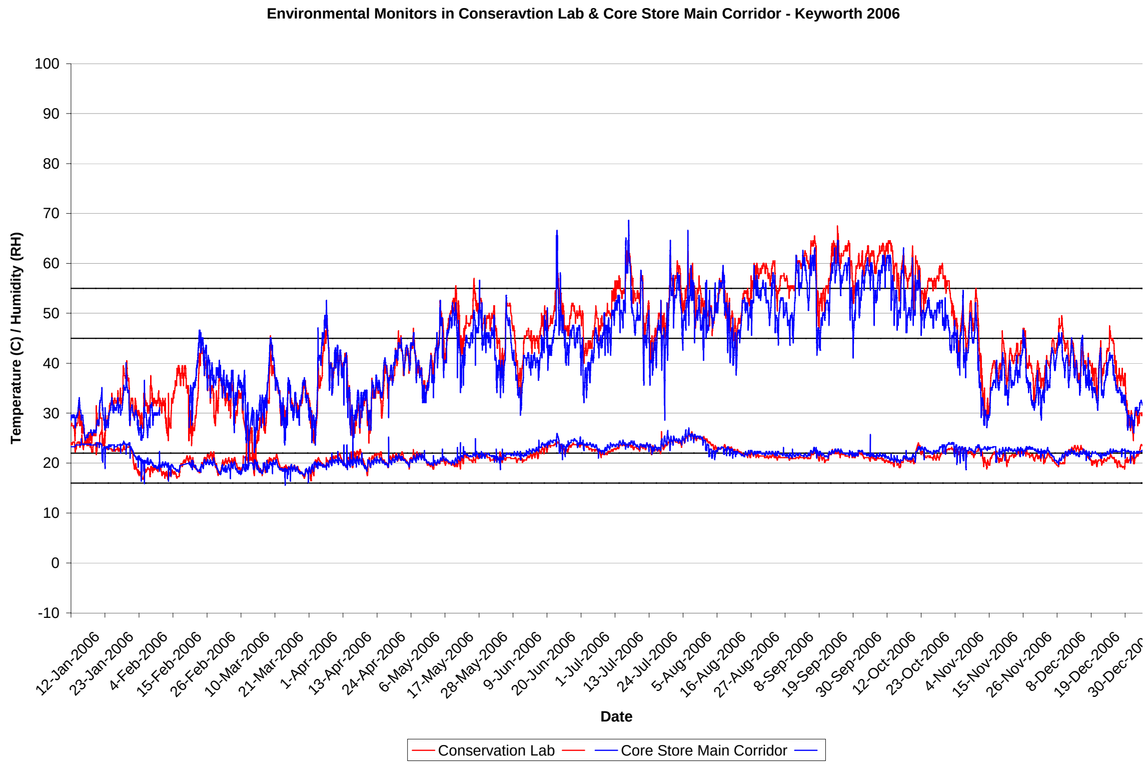

Figure 16: Conservation Laboratory & the Main Corridor of the Core Store 2006

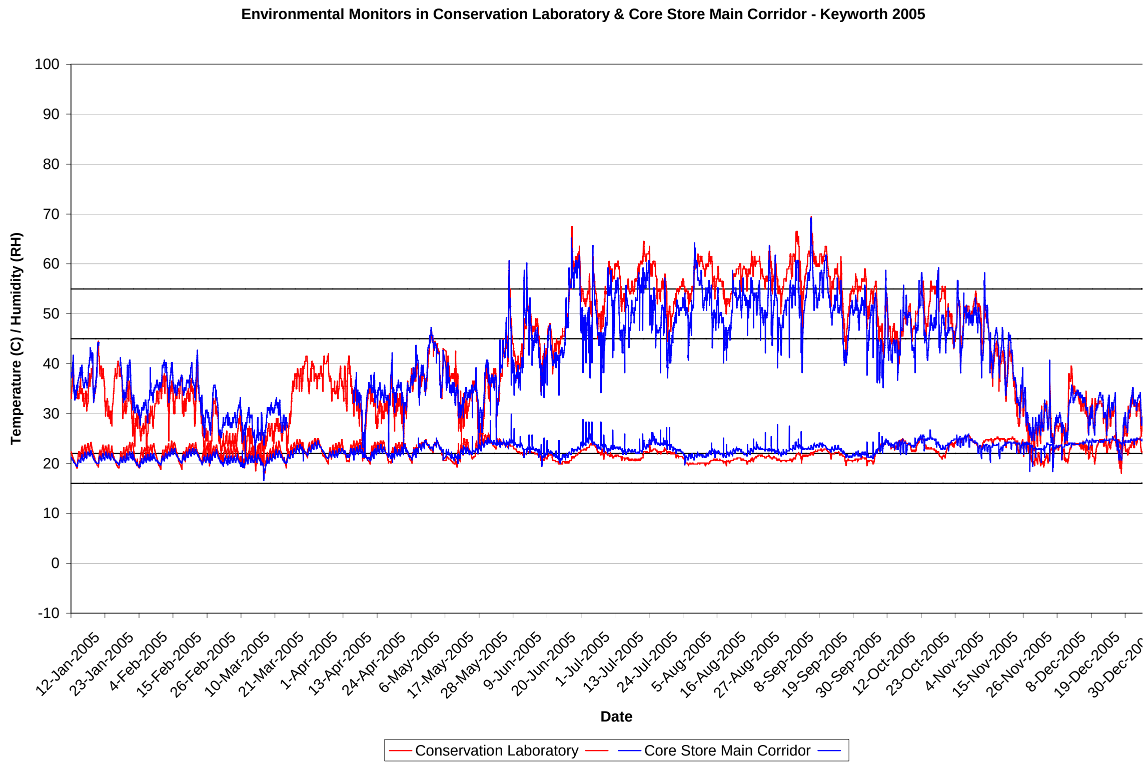

Figure 17: Conservation Laboratory & the Main Corridor of the Core Store 2005

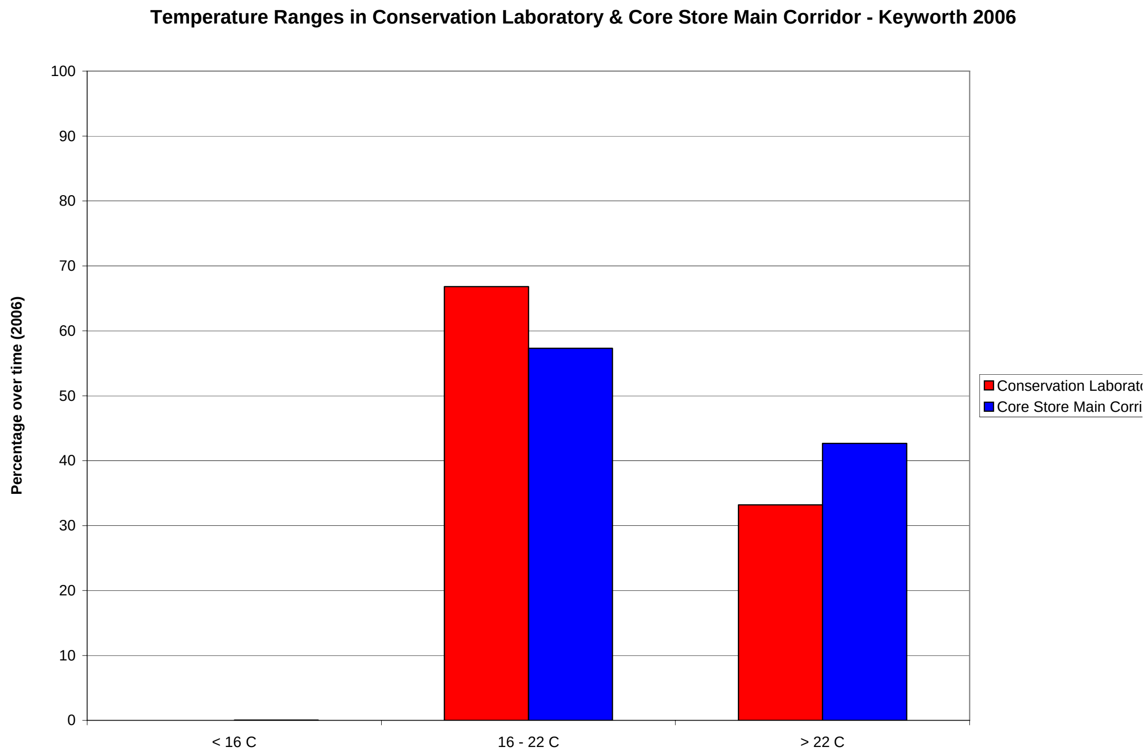

Figure 18: Histogram: Temperature ranges for the Conservation Laboratory & Core Store Main Corridor 2006

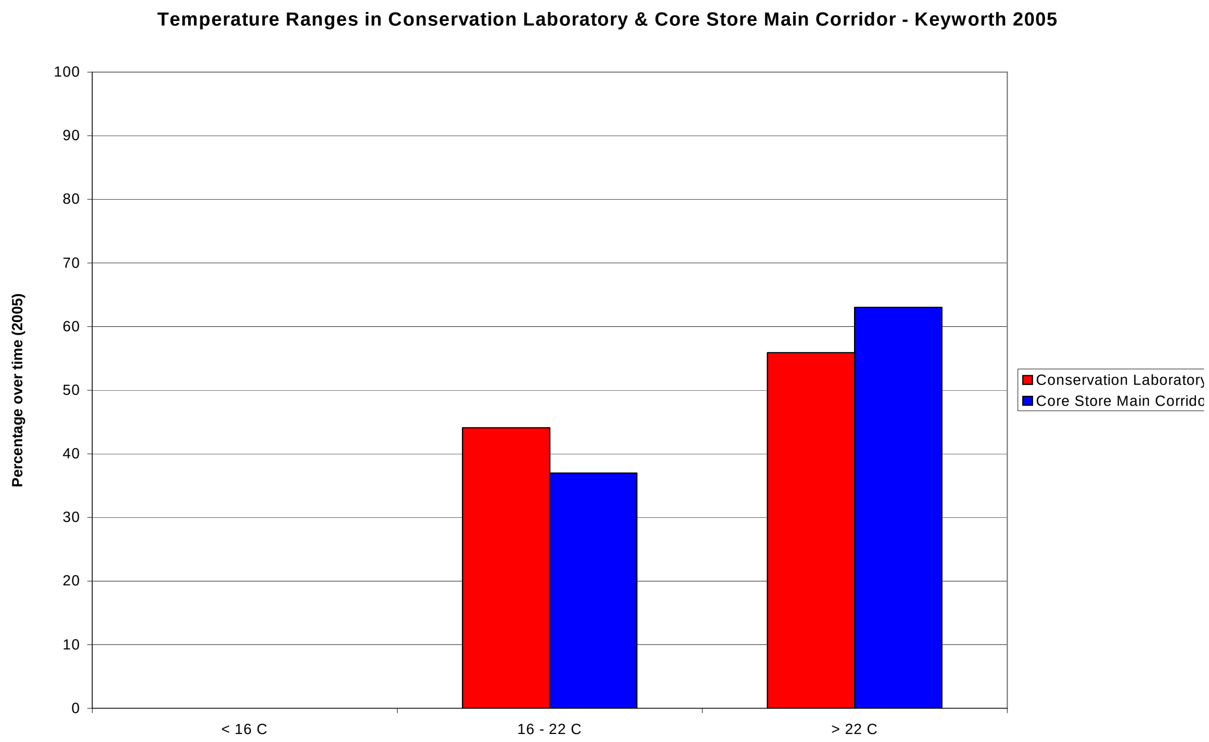

Figure 19: Histogram: Temperature ranges for the Conservation Laboratory & Core Store Main Corridor 2005

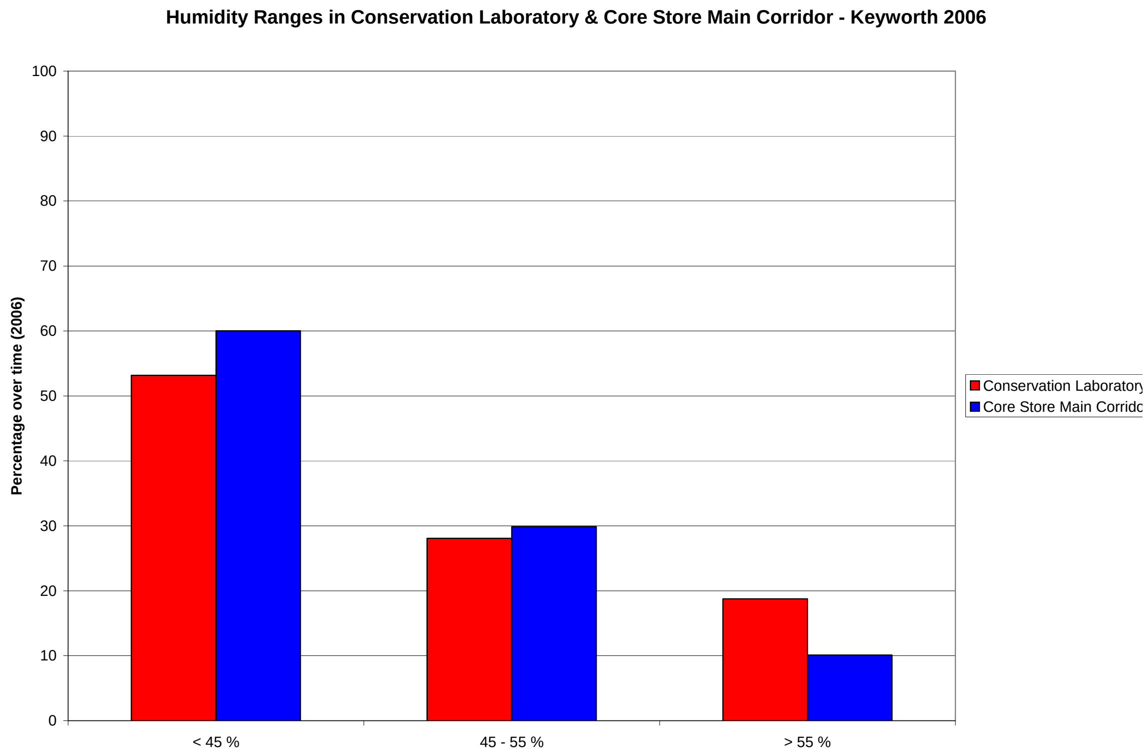

Figure 20: Histogram: Humidity ranges for the Conservation Laboratory & Core Store Main Corridor 2006

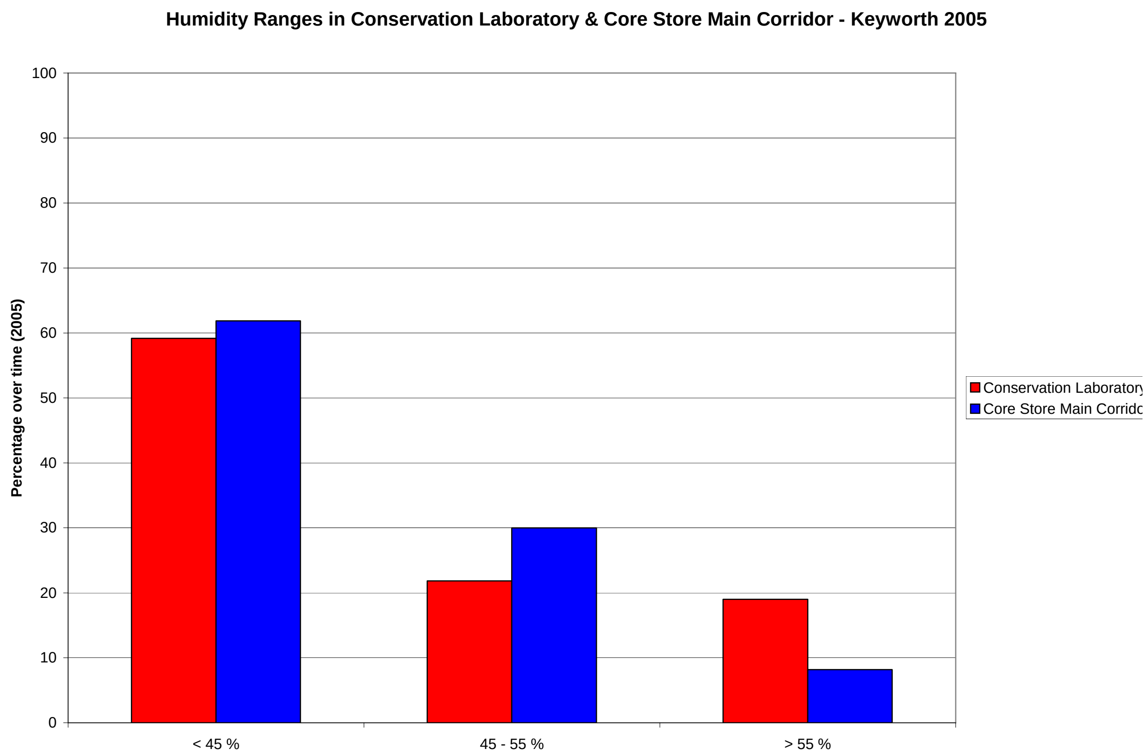

Figure 21: Histogram: Humidity ranges for the Conservation Laboratory & Core Store Main Corridor 2005

2.4.2 Cold Stores

2.4.2.1 COLD STORE NO. 2 RESULTS

When comparing data between 2006 and 2005 (Figure 22 & Figure 23), it can be seen that the results are almost identical. During 2005, there were many occasions when the temperature and humidity values peak above or below the rest of the readings, however for 2006, there are only a few such occasions recorded. When members of staff are using the cold store, and the doors are opened. The external conditions can affect the cold store readings. This is noticeable on odd occasions throughout the year, but especially at the end of February, when a cold snap occurred (Figure 5), and therefore lowered the temperature readings in the cold store by allowing air in from outside.

From the histograms (Figure 24 & Figure 25), the temperature is within the recommended 4^{o}C range (+/-2^{o}C) for 99.4% of the time compared with 99.1% in 2005. Even though there is no recommended humidity range for the cold store, this remains constant between 75% and 92 %RH, similar to readings in 2005.

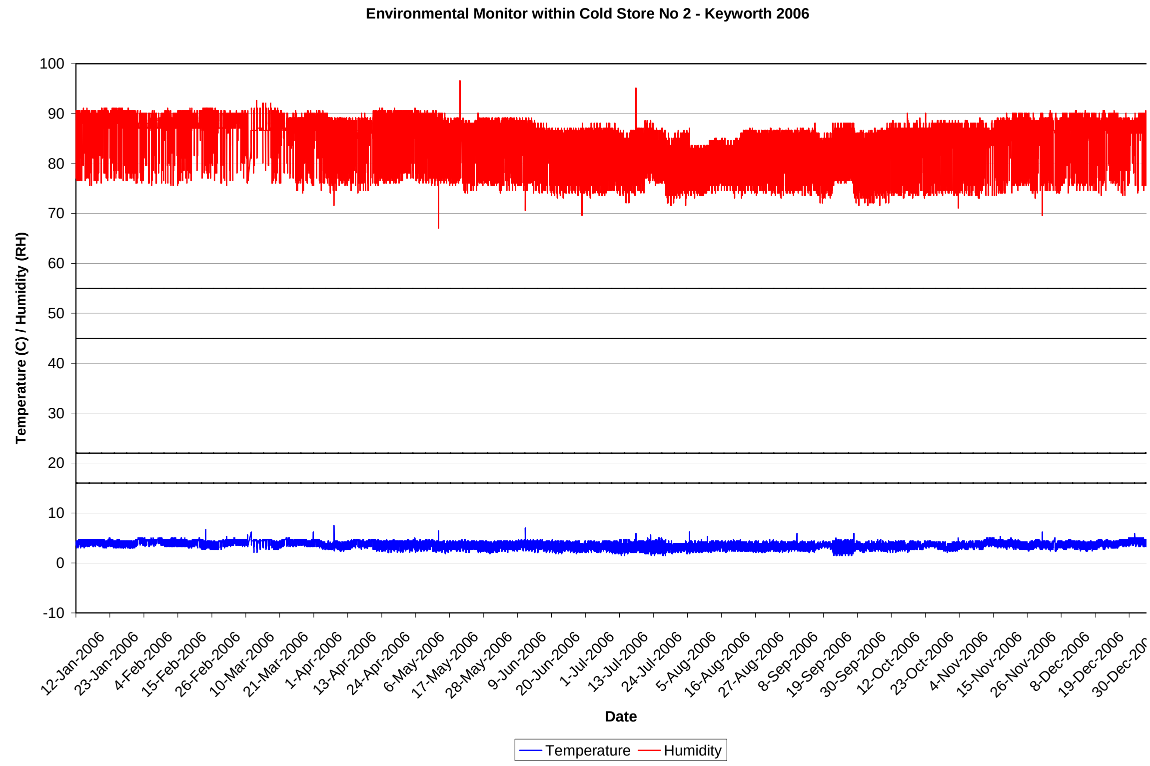

Figure 22: Temperature & humidity readings within Cold Store No. 2 - 2006

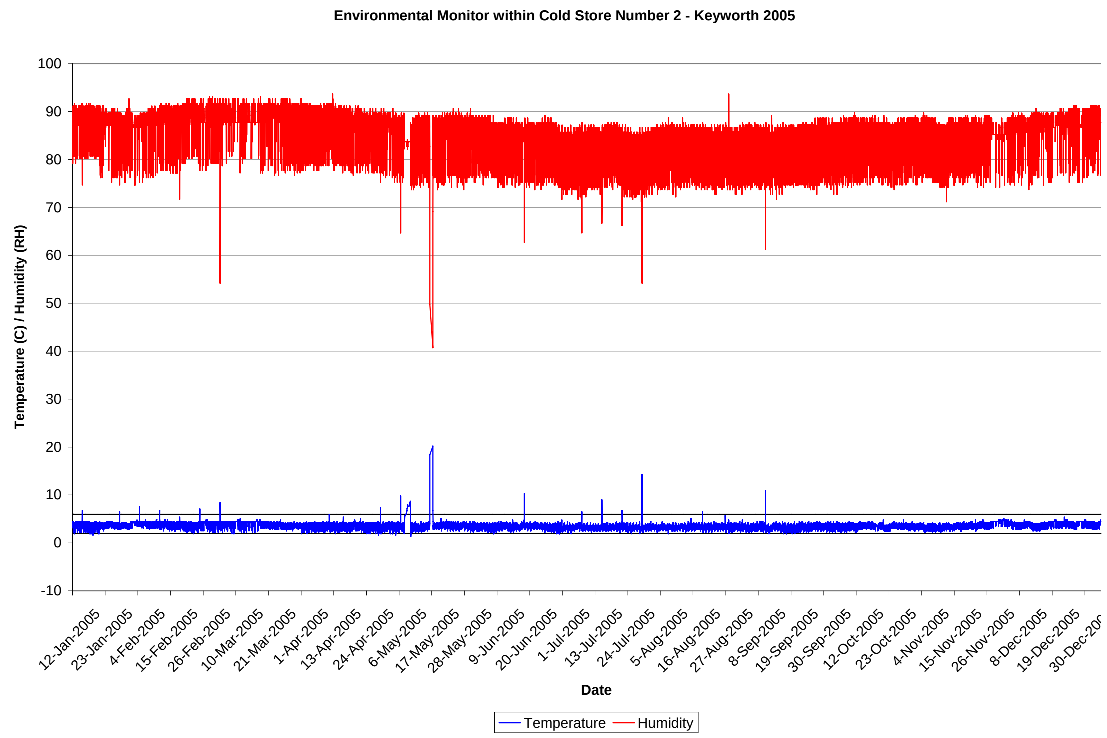

Figure 23: Temperature & humidity readings within Cold Store No. 2 - 2005

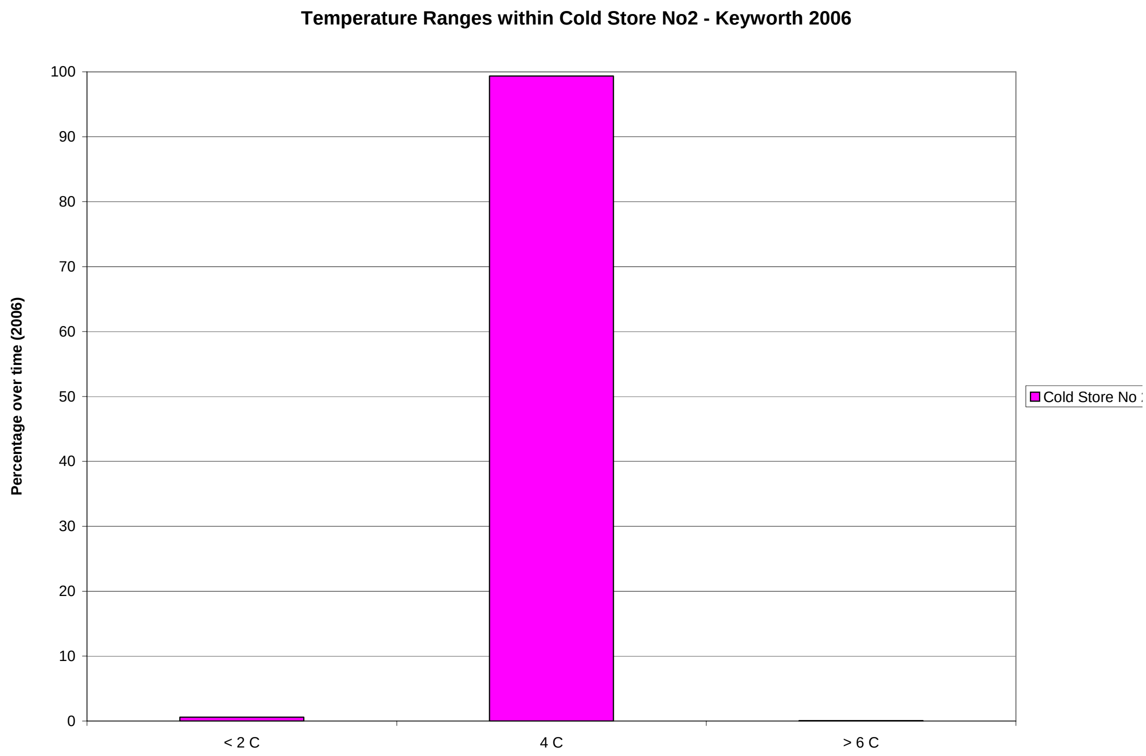

Figure 24: Histogram: Temperature ranges for the Cold Store No.2 - 2006

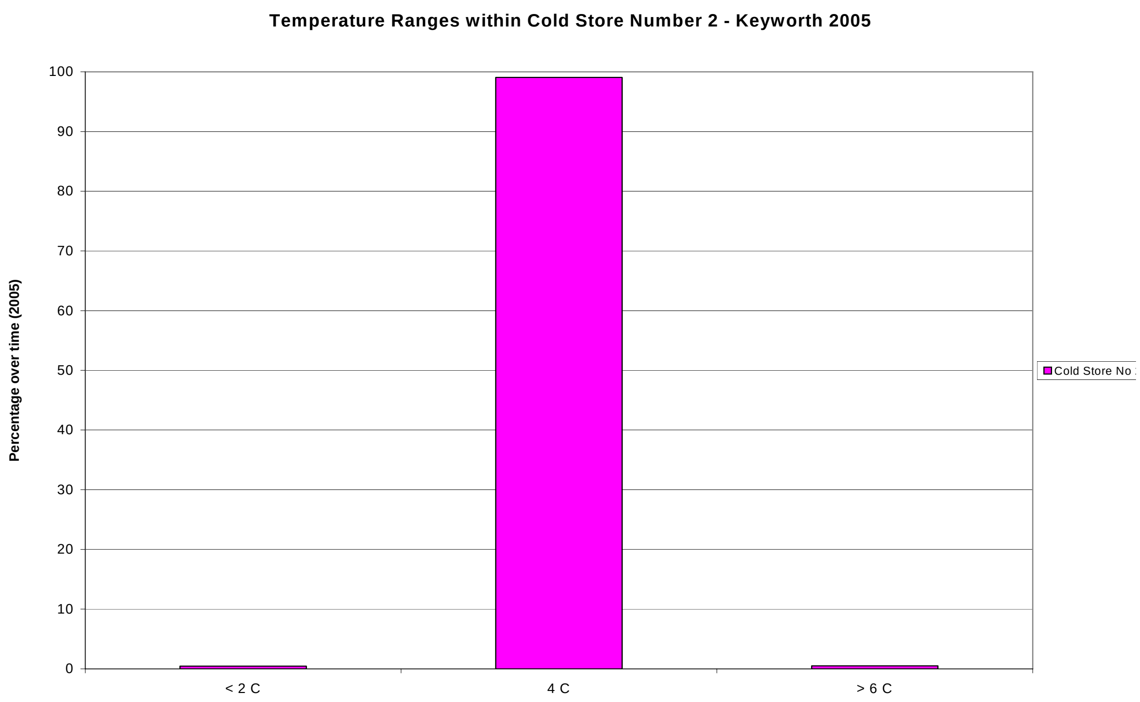

Figure 25: Histogram: Temperature ranges for the Cold Store No.2 - 2005

2.4.3 Comparisons for all monitors within the Core Store Area

Throughout this chapter, there have been many different graphs from different localities; therefore this has been clarified using a multiple histogram (Figure 26). This shows the amount of time within the associated recommended ranges, for all the localities, during 2006 and 2005. Even though the main areas of the museum have already been discussed, they will be represented in a multiple histogram with Museum monitors, in chapter 2.5.

2.4.3.1 Comparisons for all Monitors within the Core Store Area discussion

The histogram shows that all the areas monitored, are within the recommended parameter range for at least 63% of the time, whereas compared to 2005, two of the monitors only reached at least 44%. Unfortunately, the humidity readings for 2006, were not as suitable, as they are only in the recommended 45-55 RH for at least 23% of the time, compared to 28% in the previous year. As mentioned last year, these humidity readings are a cause for concern, but the majority of the material is contained within trays or core boxes, thus helping to reduce the effects the surrounding environment has on the material.

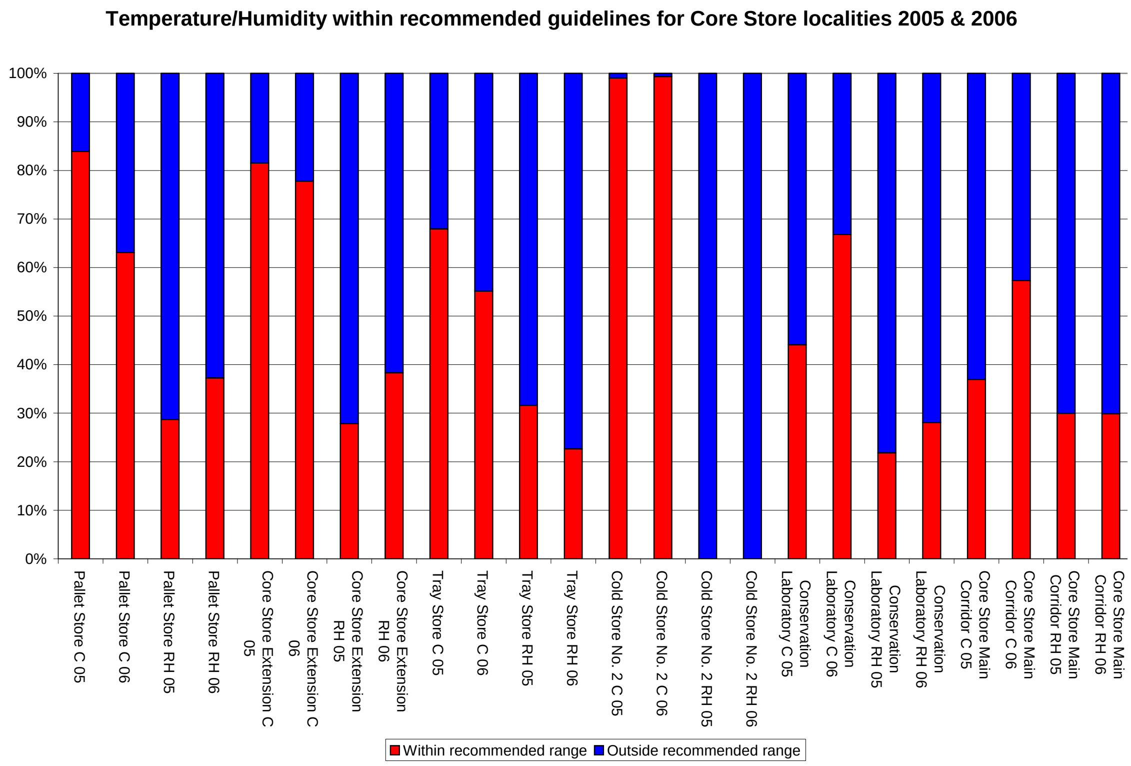

Figure 26: Temperature & humidity within guidelines for Core Store locations 2005-2006

2.5 ADDITIONAL MONITORS WITHIN THE MUSEUM 2006

2.5.1 Museum Sub-fossil Bone and the Museum Mahogany Cabinet

An additional monologger has been housed in a glass fronted wall cabinet on the ground floor of the museum that contains sub-fossil bone specimens. This monitor was activated on 9th February. Any data prior to this has not been included in the report. It was decided to place this monitor in a cabinet containing sub-fossil bone, so comparisons could be made between this material and the sub-fossil bone material stored on top of the cabinets; which is too large to be housed in the glass cabinets. Please note there is no data for the museum wall cabinet during 2005.

The humidity experiment that ran in the conservation laboratory has also been trialled in the museum next to the sub fossil bone specimens, to try and increase the humidity within that area. This consists of three plastic beakers of water (600ml) positioned at regular intervals along the shelf in front of the glass wall cabinets, beneath where the large sub-fossil bone specimens are stored. This is ongoing and commenced on the 1st February.

The museum's thermohygrograph was decommissioned at the end of May, so this data has been omitted from the report.

The suite of monitors within the museum now comprises of:

- Monitor at the rear of the museum on the display bench (First Floor)
- Monitor within mahogany cabinet drawer (99/32) (First Floor)
- Monitor on top of a wall cabinet, next to large sub-fossil bone material (Ground Floor)
- And a monitor within a glass wall cabinet containing sub-fossil bone material (Ground Floor)

Please note, the ideal parameters for sub-fossil bone should be 18-22°C and 50-55% RH, *Child (1994).*

Background information on these existing areas and monitors can be found in the report *Shepherd & Tulloch 2004*, section 2.5.

Plate 1: Museum Glass Wall Cabinet

Plate 2: Humidity Experiment Museum

2.5.1.1 MUSEUM SUB-FOSSIL BONE AND THE MUSEUM MAHOGANY CABINET RESULTS

The graphs detailing the results for the Museum Sub-fossil bone and the museum cabinet during 2006 and 2005 are shown on Figure 27 and Figure 28. The humidity experiment for the sub-fossil bone has been graphed on Figure 29, whilst the annual weather graph is on Figure 5.

For the temperature readings, all the monitors through the spring follow a weekly cycle which is effected by the central heating being on during the week and off during the evenings and the weekends. The monitor in a 1st floor cabinet is still follows this pattern but is less affected by the central heating. This shows the ability of the mahogany cabinets, combined with the glass lidded drawers at buffering the changes taking place in the museum environment.

From the graph, it is difficult to see what the museum wall cabinet results are reading during this time, however it is not out of sync with the other monitors; nor is it recording values outside the 18-22°C range. As for the requirements of the large sub-fossil bone specimens on top of the cabinets; these appear to be within the 18-22°C range for the majority of time. The only exception to this is during the evenings and weekends, when the temperature within the museum falls. Comparing this to 2005, during the same time of year; there seems to be an improvement, even though the weekend patterns still occur, but are less pronounced.

As the external temperature increases, towards the summer and the internal heating is switched off, the temperature seems to follow that of outside, especially during the hotter summer months. A similar pattern for the museum cabinet has occurred which follow those of the 1st floor monitor, but with less fluctuation in readings. During mid August, there is a period when the museum cabinet showed higher temperature readings and lower humidity values. This coincided with when the tray containing this monitor was moved to the core store for a demonstration display. Additionally, the museum wall cabinet monitor on the ground floor shows lower, more stable temperature readings than the monitor on top of the sub-fossil bone cabinet. This appears to confirm that the glass wall cabinets are buffering the temperature to some extent.

Throughout the autumn and winter, all the monitors show temperature readings that fluctuate within the 16-22°C range, whilst the museum wall cabinet and mahogany museum drawer monitor display more stable readings. All monitors during the end of October-beginning of November showed a dramatic rise in temperature. The cause was due to a number of factors; high external autumnal temperatures, the central heating being operational across the site, whilst the air extraction/ air circulation system was non operational in the museum. This caused the temperature to rise to 26°C, similar to summer temperatures. These high temperatures caused the humidity levels to fall within the aisles of the museum. Facilities management were informed of this situation and the air circulation / air extraction system was turned on which then allowed the temperatures to return to their normal levels.

The humidity readings fluctuate more dramatically compared to the temperature readings. The monitors outside the drawers and cabinets appear to follow a more stable pattern than 2005, even though they show readings above and below the recommended 45-55%RH for general conditions and 50-55%RH for sub-fossil bone. The humidity levels are below the 45%RH threshold during the winter, due to the central heating being operational. Whereas; the summer humidity values are directly effected by humid external conditions and the warming effect of the building via solar gain.

The monitor that is situated in a mahogany and glass drawer within a mahogany cabinet offers the best protection from changing humidity levels within the museum and outside. (The majority of the museum collections are stored this way). Even though the readings are not constantly within the recommended humidity parameters, they do show more stable conditions, which therefore will lead to less damage to the specimens occurring. There are occasions where the humidity suddenly differs from the surrounding values. This is a reflection of changing conditions when the monitors are removed from their locations for downloading.

The recordings from the monitor within the glass cabinet containing the sub-fossil bone material, shows us it provides some level of protection to the material, even though these still do not provide ideal conditions for the storage of this type of material. It must be noted that there are no additional measures implemented at this time to regulate the humidity values to around 50-55%RH for sub-fossil bone. Therefore it can be seen that the glass cabinets offer a more stable environment for the sub-fossil bone material, however this is not entirely satisfactory and may need improvement.

The monitor near the large sub-fossil bone specimens, which are too large for the cabinets; show humidity readings similar to those on the ground floor. An experiment was run during 2006 to try and raise the humidity, see Figure 29. It is difficult to determine whether this experiment has been successful at increasing the humidity levels around the exposed sub-fossil bone material. The graph shows a continual level of evaporation for all three beakers used in this experiment, throughout the year. The highest rates (22-32%) during the winter months where warmer internal temperatures cause this evaporation. This is particularly noticeable for location two, which is situated in an area of poorer airflow. The readings taken in late summer show the lowest evaporation rates around 3-5%, even though temperatures are higher in the museum, but for a shorter duration compared to the winter months.

2.5.1.2 Discussion for the Museum Sub-fossil Bone and The Museum Mahogany Cabinet through Histograms

Figure 30 to Figure 33 summarise the temperature and humidity within the associated recommended ranges. Please note that no data exists for museum wall cabinet during 2005, so no comparisons can be made.

All areas have seen temperature increases within the respected recommended ranges, with the lowest being for 72.4% of the time. Whereas the museum wall cabinets under the parameters for sub-fossil bone (18-22^{o}C) is within range for 91% of the time, even though no additional measures have been taken to maintain these temperatures.

The amount of time below the recommended ranges, for all the monitors therefore has decreased, with the greatest change being on the 1st floor of the museum, on the display bench, being 0.7% of the time, compared to 6.6% in 2005.

For readings above 22^{o}C, there has been a decrease in the percentage of time spent to around 20% for both monitors on the 1st floor of the museum, whereas the monitor next to the large sub-fossil bone specimens has only seen a 0.8% decrease to 14.4% of the time recorded.

The humidity values are not as promising, where both monitors outside of the cabinets on both floors have seen a slight decrease. The major change is for the museum cabinet, which has decreased from 77.8% to 22.8% of time being spent within the recommended range. Direct comparisons cannot be made as monitoring for this museum drawer only commenced from May 2005. The amount of time within the 45-55% RH range is similar to data from the other monitor on the same floor, which would suggest that humidity within the museum is effecting the readings.

All the pre-existing monitors, excluding the wall cabinet, have shown similar figures outside their recommended humidity ranges, compared to 2005. The monitor within the glass wall cabinet is also showing similar readings to the other sub-fossil bone monitor. This is quite promising considering that no additional measures have been taken to improve this environment. Any future adjustments to this microclimate should be beneficial, as it would hopefully improve the conditions for storage within the glass fronted cabinets.

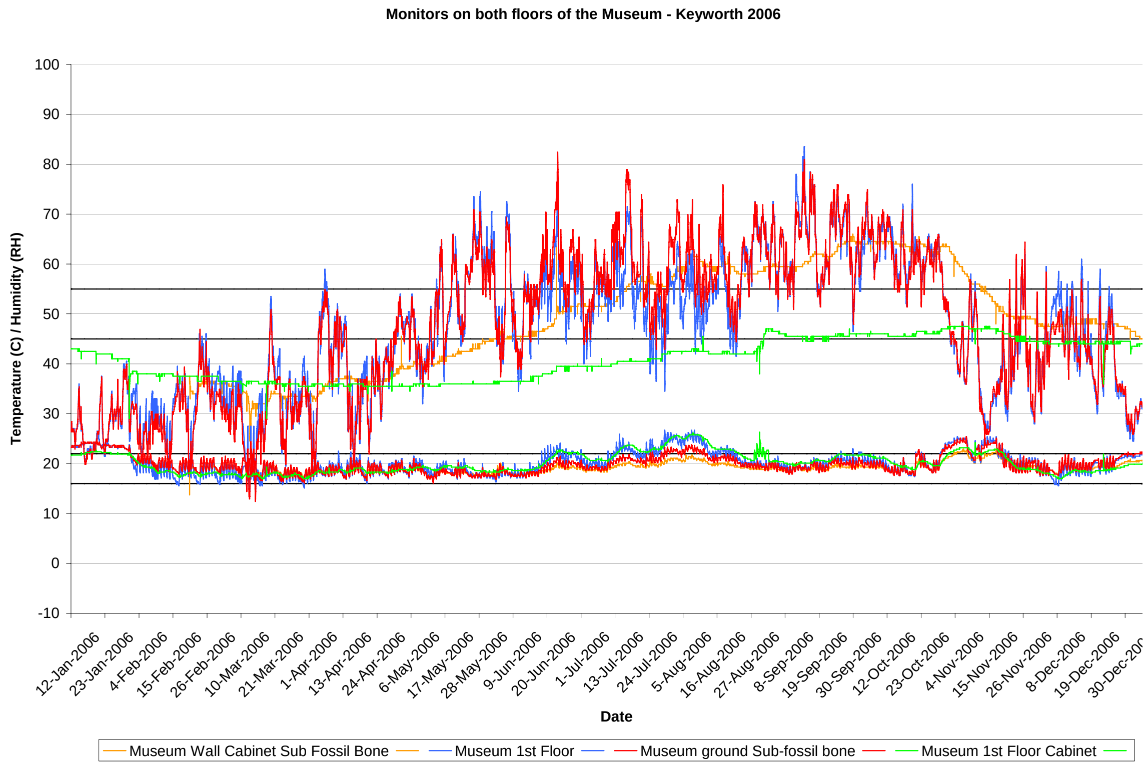

Figure 27: Temperature and humidity readings Museum Sub-fossil bone and Museum Cabinet 2006

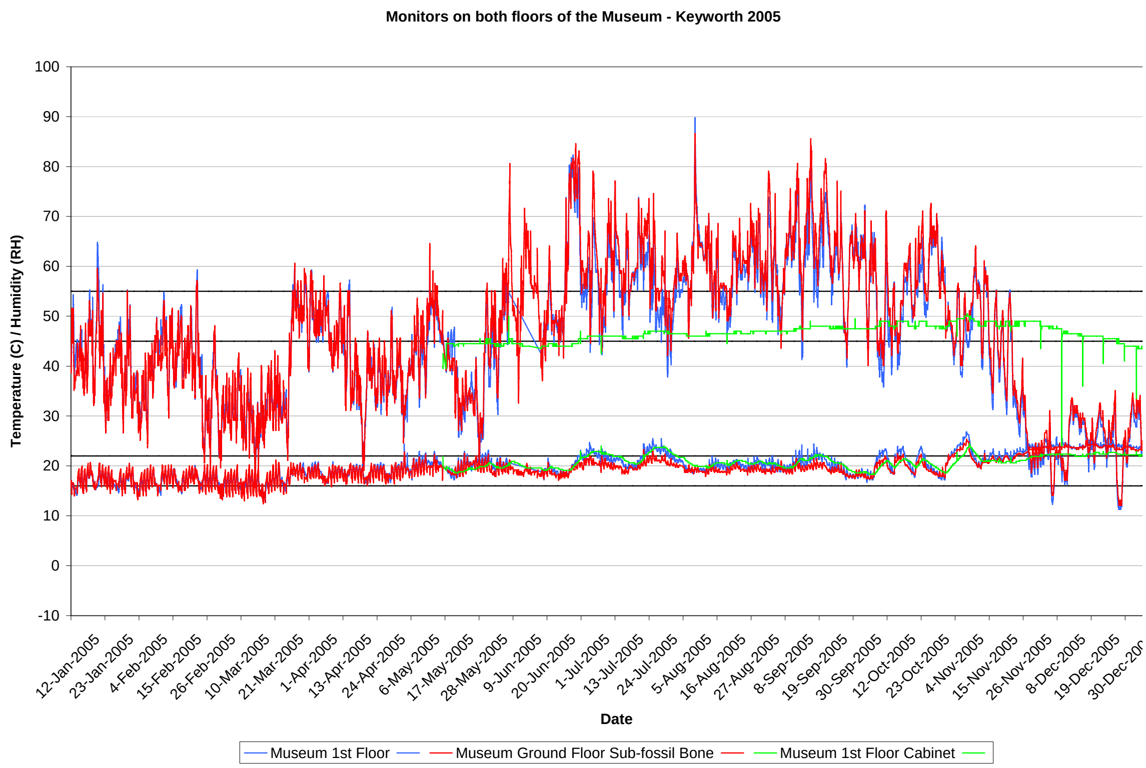

Figure 28: Temperature and humidity readings Museum Sub-fossil bone and Museum Cabinet 2005

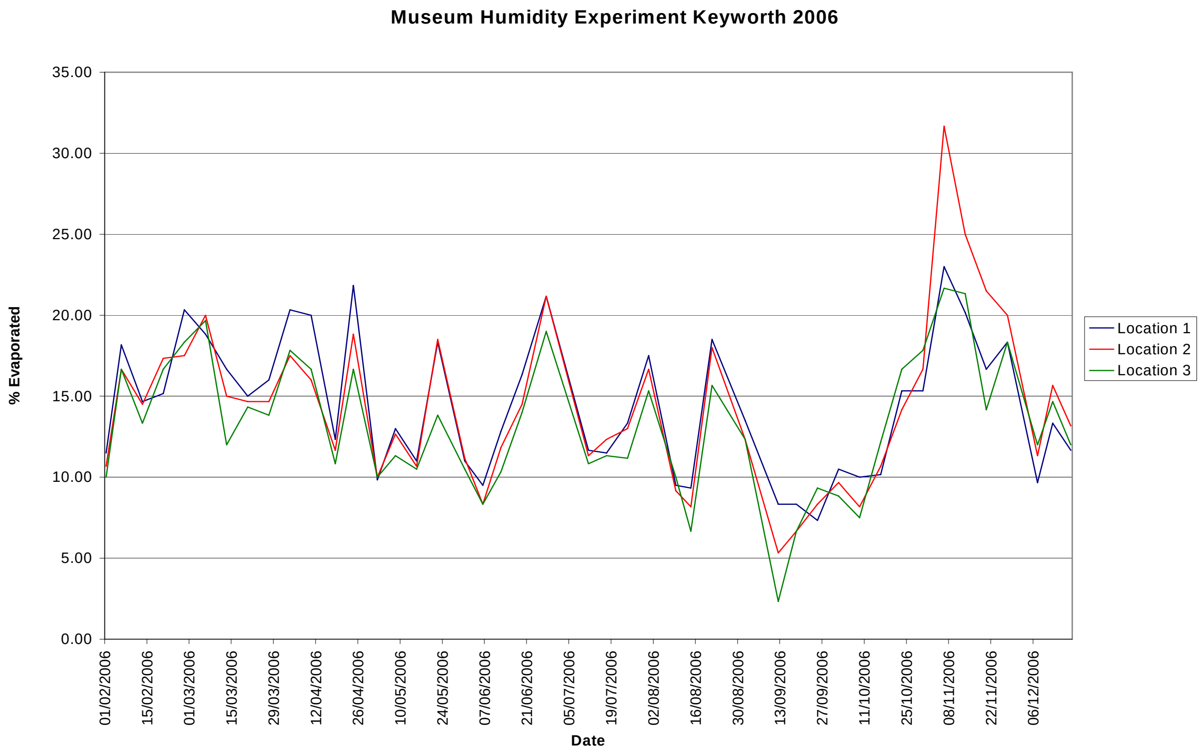

Figure 29: Museum Humidity Experiment - Keyworth 2006

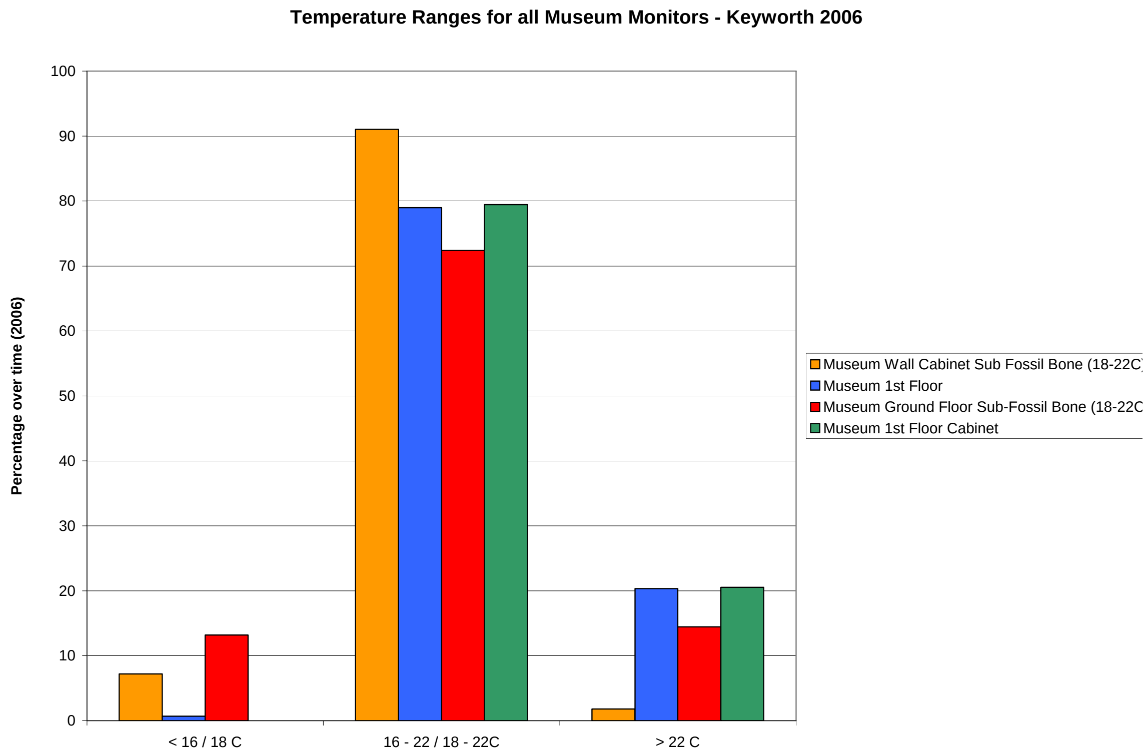

Figure 30: Histogram: Temperature ranges for all Museum monitors 2006

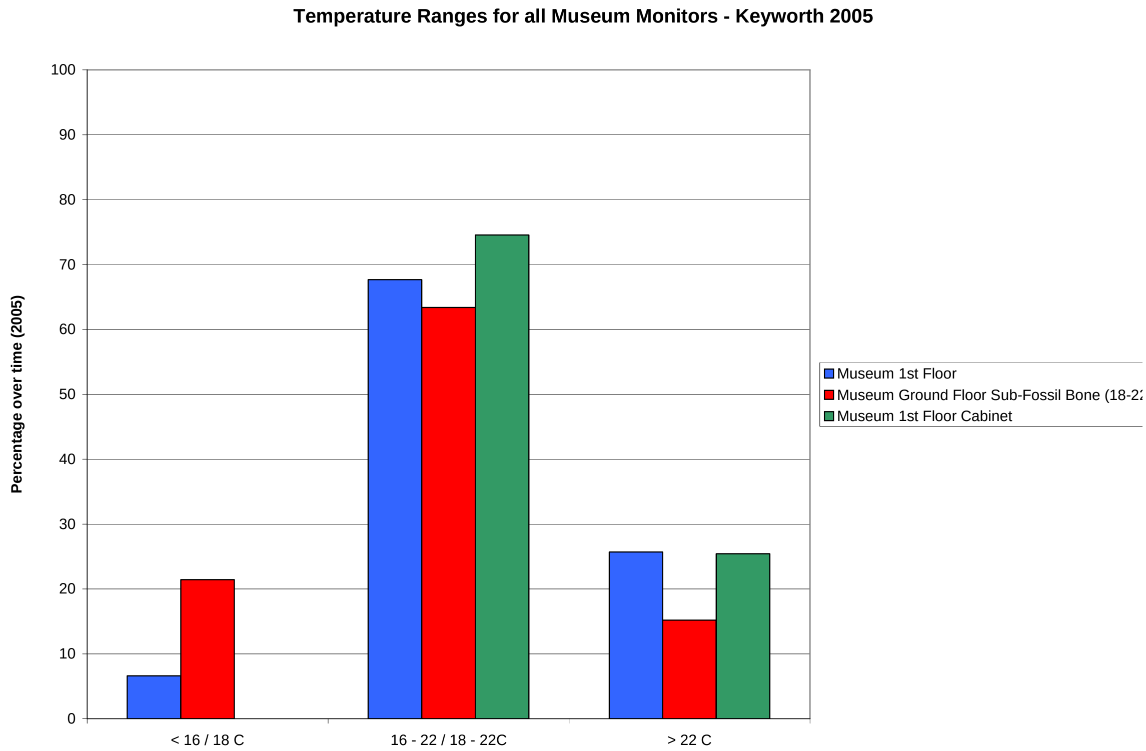

Figure 31: Histogram: Temperature ranges for all Museum monitors 2005

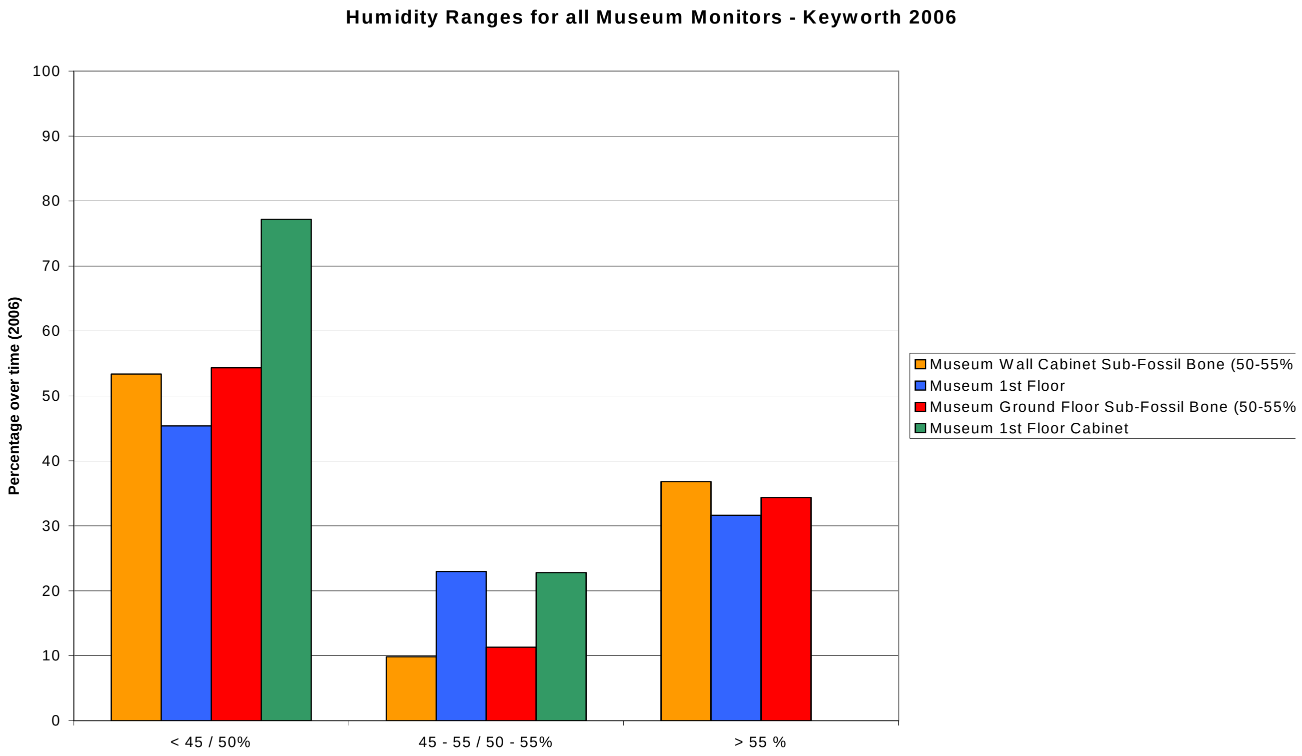

Figure 32: Histogram: Humidity ranges for all Museum monitors 2006

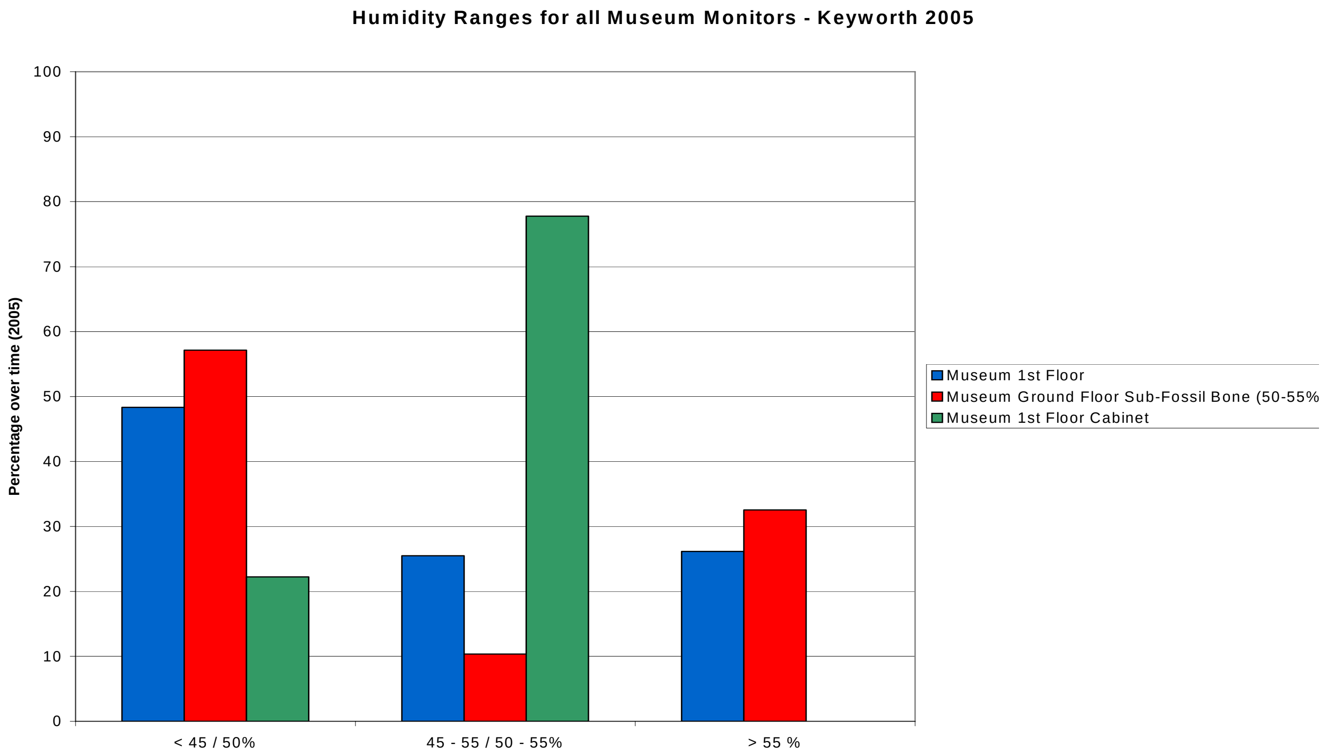

Figure 33: Histogram: Humidity ranges for all Museum monitors 2005

2.5.2 Comparisons for all Monitors within the Museum area

For all the localities within the museum during 2006 and 2005, a histogram (Figure 34) has been produced to show the percentage of time within and outside the acceptable parameters. Please note that the 1st floor museum cabinet monitor only commenced readings during May 2005; therefore comparisons with 2006 will be inaccurate.

2.5.2.1 COMPARISONS FOR ALL MONITORS WITHIN THE MUSEUM AREA DISCUSSION

All the monitors within the museum have shown readings within their respective recommended temperature range for at least 72% of the time, with the highest readings of 91% in the museum wall cabinet housing the sub-fossil bone specimens. This is an improvement when compared to 2005. As the time spent within the recommended parameters was 63.4%, this was recorded on the monitor adjacent to the large sub-fossil bone specimens on the ground floor.

The humidity readings in 2006 show that the first floor monitors show conditions are only acceptable for around 23% of the time. In comparison, the ground floor only provided suitable conditions for about 10% of the time.

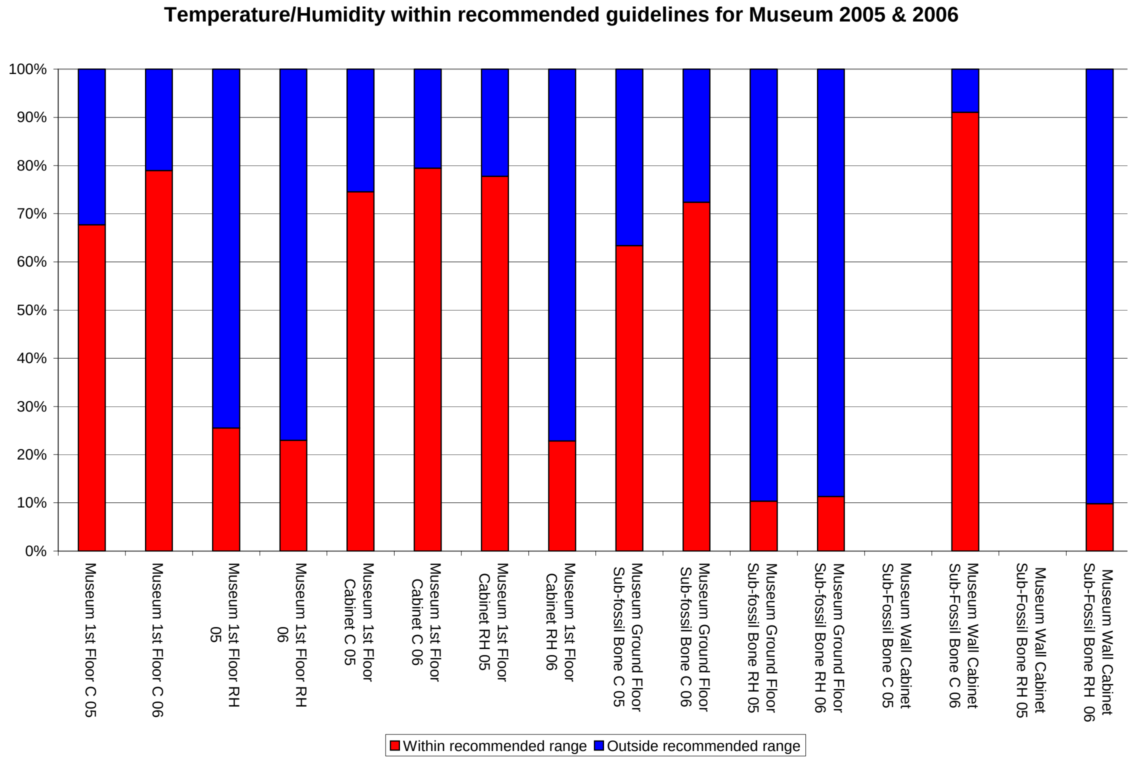

Figure 34:Temperature / Humidity within guidelines for the Museum 2005-2006

2.6 MONITORING WITHIN THE NGRC 2006

The NGRC is a place of deposit for public records; as a result it should be meeting the following standard, The *British Standard BS 5454:2000*, which recommends for the preservation of archival documents, the temperature should between 16-19°C, whilst the Relative Humidity should be between 45-60%RH.

2.6.1.1 MONITORING WITHIN THE NGRC RESULTS

An annual graph showing all the areas within the NGRC is shown on Figure 35, with comparisons under the same parameters for 2005, shown in Figure 36. For the percentage of time where readings are within and outside the acceptable parameters are shown in Figure 41. External weather readings for 2006 are shown on Figure 5.

Throughout January all the temperature sensors within the NGRC are showing constant readings around 23°C. From February to May the temperature seems to follows a weekly cycle, which reflects the fact that the heating is operational during the week and not during evenings and weekends. The only possible explanation for this cycle not occurring during January may be that the weather was unseasonably mild with temperatures of around 10°C. During this period, the strong room was recording higher temperatures than the records room, but this then switches in February when the weekly temperature cycle occurs.

During spring 2006, the temperature readings in the strong room fluctuate less than the adjacent records room, even though it is not within the recommended 16-19°C range. There is however, an improvement over 2005 for the same period.

From May to August, the temperature is elevated for longer in all areas compared to 2005, caused by a longer and hotter summer. During the first part of the summer, the strong room showed lower readings, but as the months progressed and external temperatures rose causing the strong room to become hotter as the building absorbed heat from the Sun, when compared to the records room which is better ventilated.

For the autumn and winter, the temperature readings are more stable than 2005, except for two changes, these coincide with sudden decreases in external readings, even though the central heating was operational which usually compensates for this. The combination of the mild weather and the heating being operational, have caused elevated readings within the NGRC.

Though it is difficult to view from the graph, the temperatures within the cardboard records box compared to the aisle are identical throughout the year. Such patterns during 2005 were the same, which shows that the cardboard record boxes are not giving any buffering from the changing temperatures within the records room.

For the humidity values, the 2006 data follows a similar pattern to 2005, with the strong room providing ideal conditions for the majority of the time.

The monitors within the records room aisle and the records box show that for 30% of the time, conditions are below the recommended 45-60% RH range. Whilst during mid summer, the humidity begins to creep within the 45-60%RH range more often. The monitor within the record box has shown higher readings than the monitor in the aisle. This is noticeable during the winter of 2006. Such occurrences could be because of the latent heat from the aisles and boxes still remaining from the summer, together with the use of scanners and computers in that area; whilst the central heating is on.

Humidity within the records room fluctuates throughout the year. These readings are not within the recommended range and therefore do not provide ideal storage conditions for paper records. It can be seen that the cardboard record boxes do provide a more stable environment but still outside the recommended parameters.

2.6.1.2 Discussion for the NGRC through Histogram

Figure 37 to Figure 40 summarises the temperature and humidity within the associated recommended ranges.

Comparing 2005 to 2006, there has been a marginal improvement in the number of readings that fall within the recommended 16-19°C parameter, however the NGRC is clearly not proving the ideal storage conditions for paper records, as the amount of time spent above the 19°C limit, is still above 97% for all areas within the NGRC monitored.

The amount of time where the humidity readings are acceptable has decreased in 2006, when compared to the reading from 2005. As a result, the quantities of readings that are now below the minimum 45%RH threshold have increased.

The strong room is providing a more suitable environment for archival documents than the strong room.

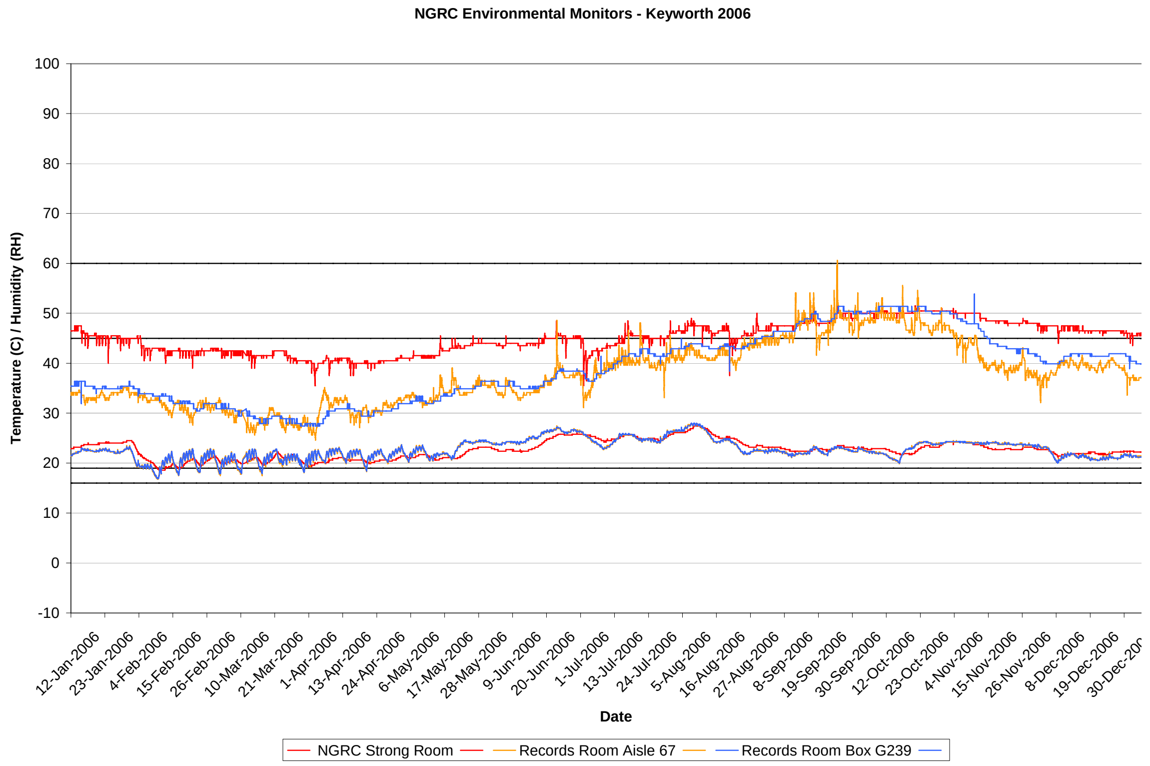

Figure 35: Temperature and humidity values within the NGRC 2006

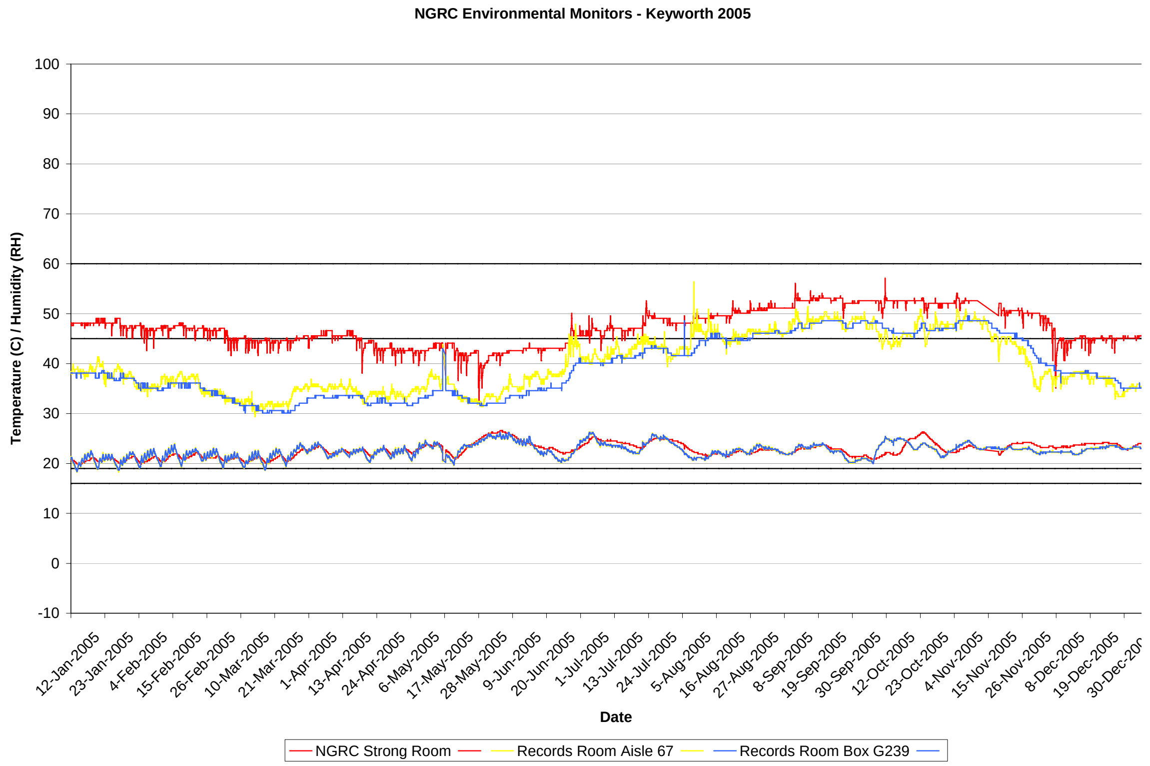

Figure 36: Temperature and humidity values within the NGRC 2005

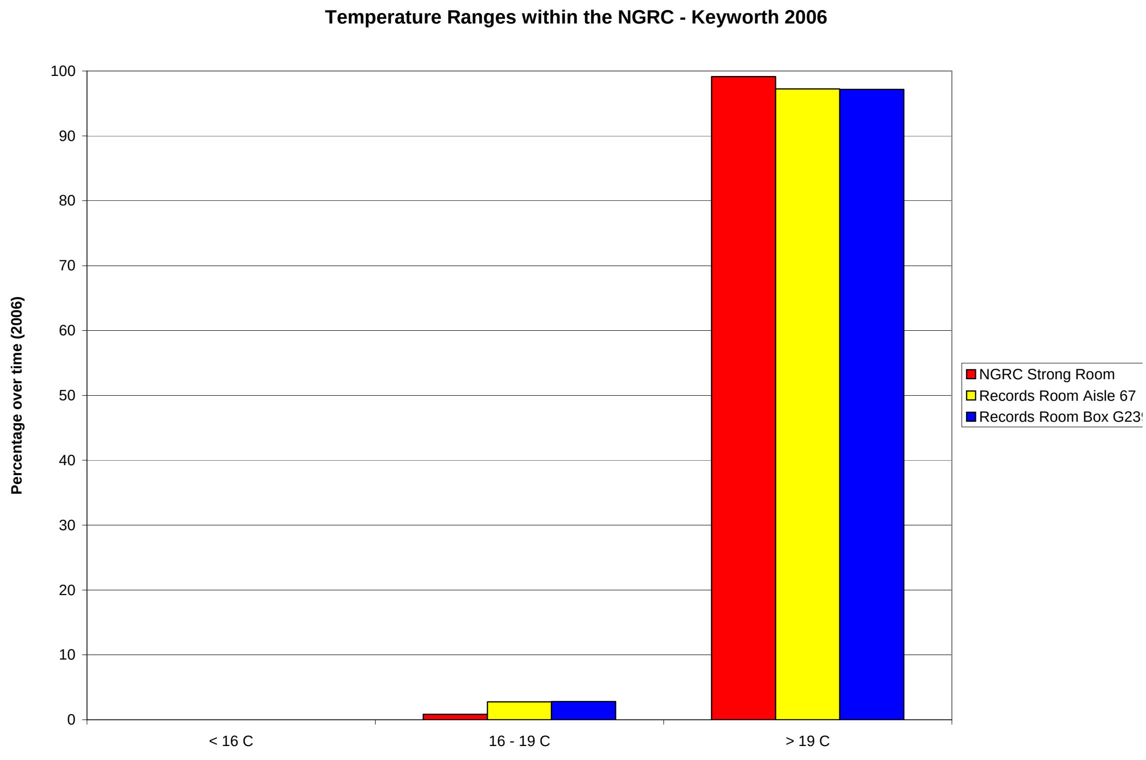

Figure 37: Histogram: Temperature ranges within the NGRC 2006

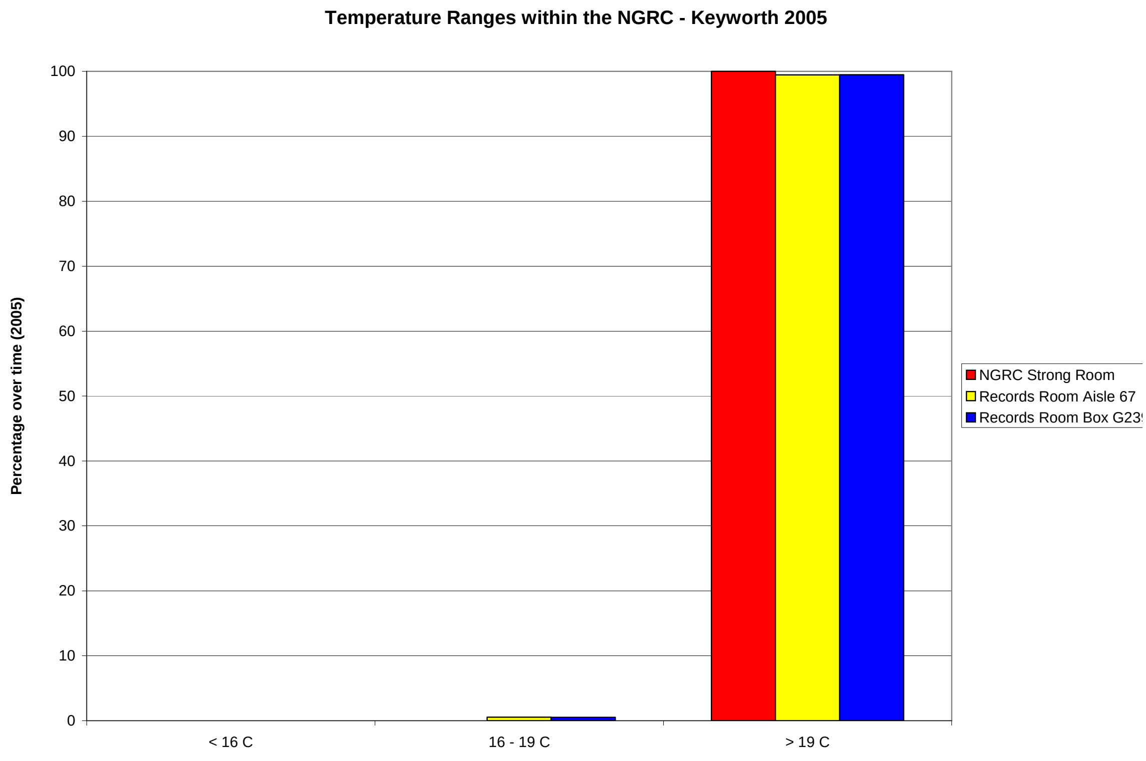

Figure 38: Histogram: Temperature ranges within the NGRC 2005

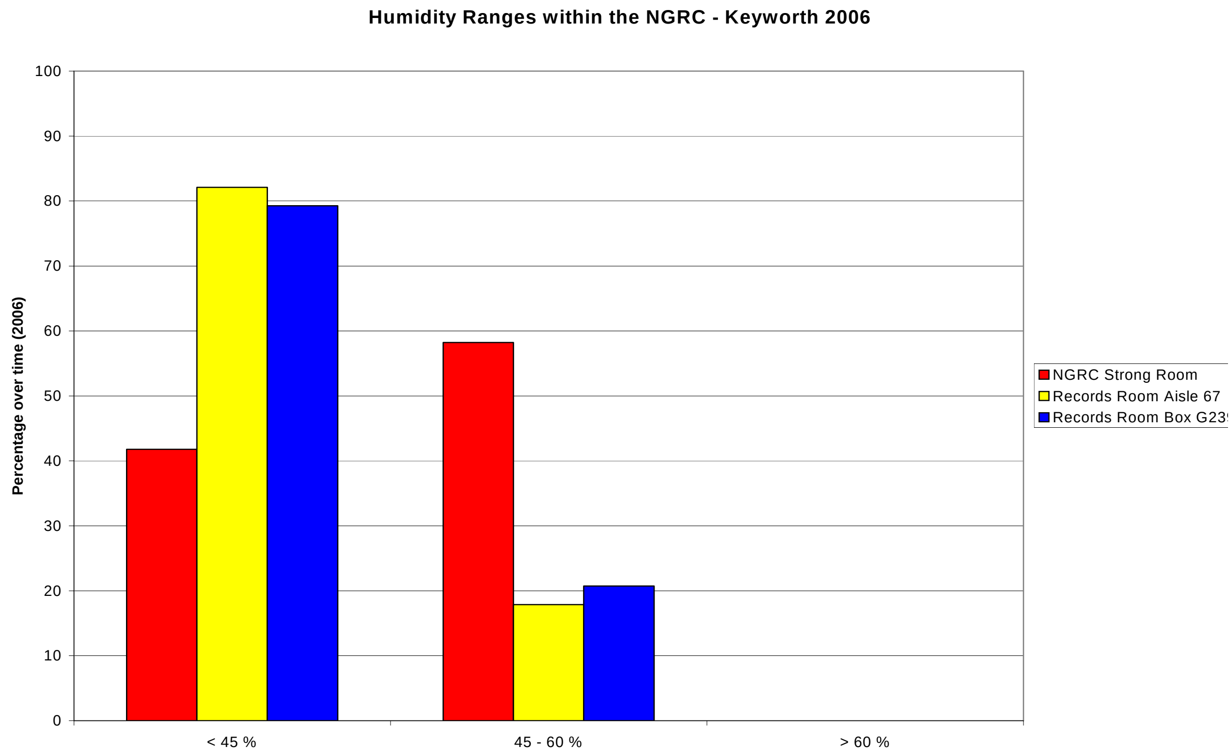

Figure 39: Histogram: Humidity ranges within the NGRC 2006

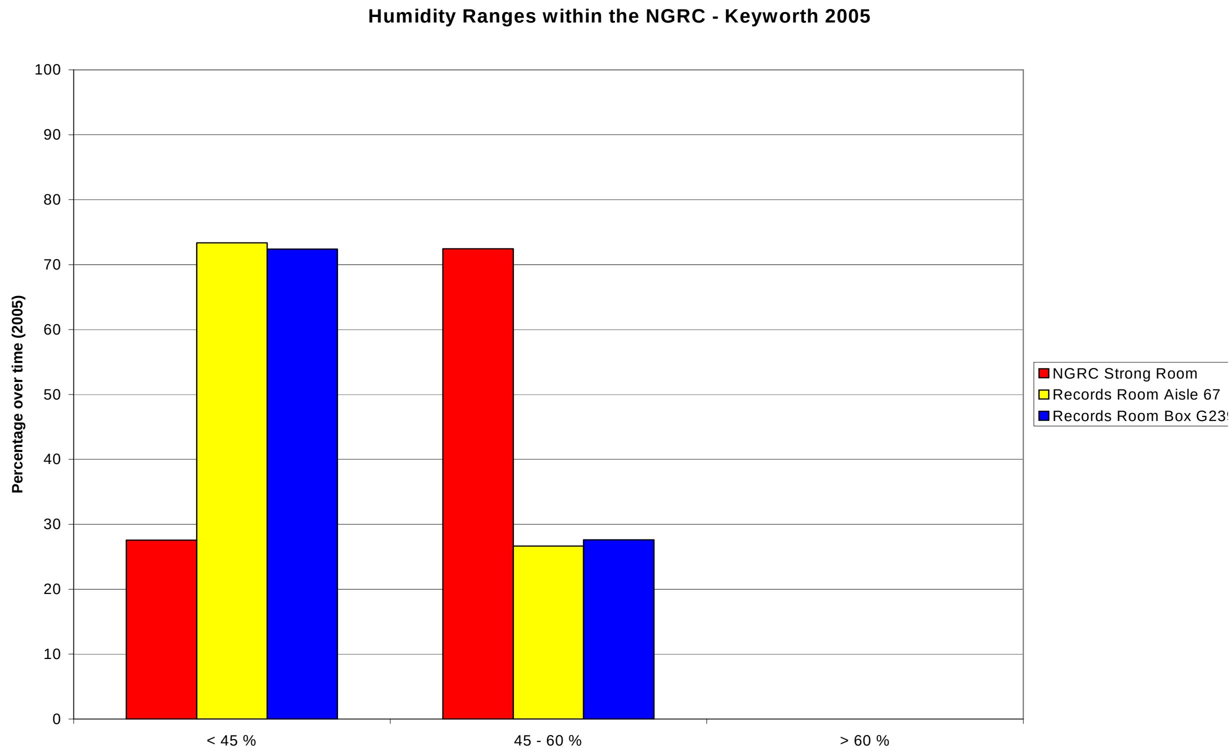

Figure 40: Histogram: Humidity ranges within the NGRC 2005

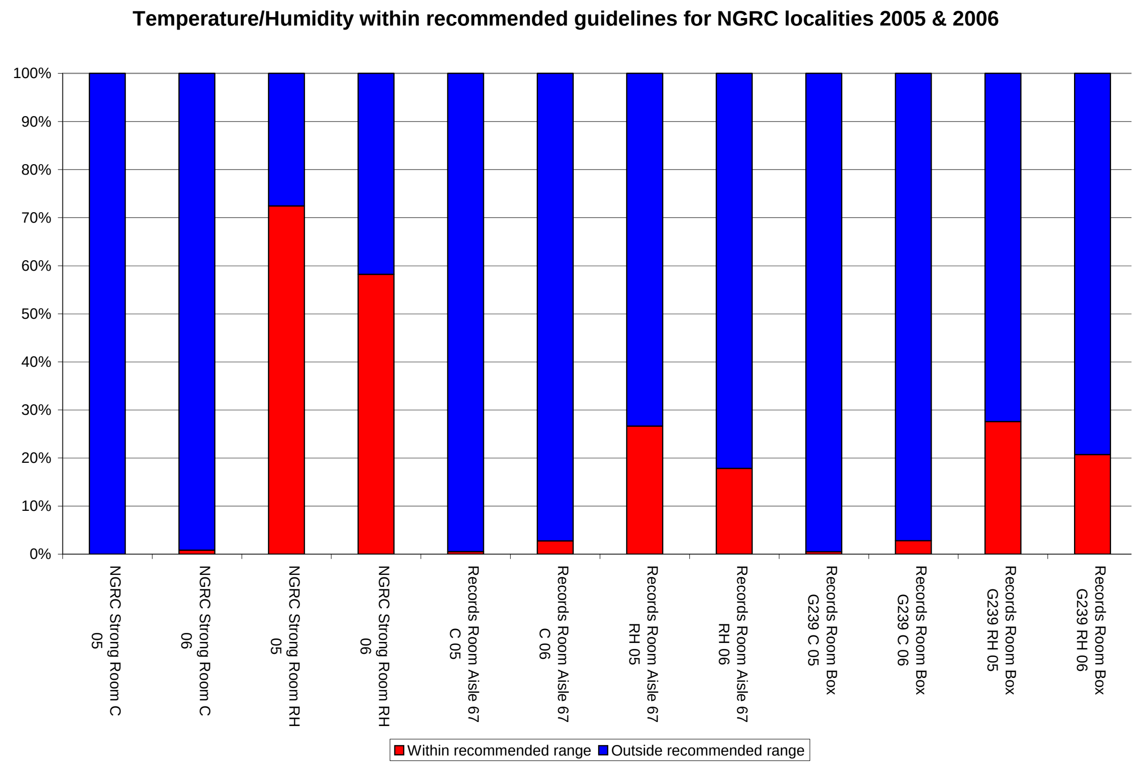

Figure 41: Temperature / Humidity within guidelines for the NGRC 2005-2006

2.7 MONITORING WITHIN JURASSIC TOWERS 2006

Jurassic Towers is primarily an office area for registration (cataloguing) and databasing staff. There is currently room for 9 staff. Although not originally intended for records, an area has been made available for map and plan storage. Jurassic Towers is situated on the top floor (northern corner) on of the NGRC, which is on the North West edge of the site. The building is metal clad with strip glazing, the stairwell is brick built, whilst the roof is flat insulated to the requirements of the buildings regulations at the time.

Environmental monitoring was originally installed to deal with staff concerns about extremes of temperature, but now also provides the necessary recording for the plans collection. Some work, such as lagging pipes, has been carried out this year to improve temperature stability.

A Digital Memory Thermo-hygrometer monitor has been positioned at waist-height on the northwest wall. This monitor records both current temperature and humidity, and the maximum and minimum readings once the monitor has been reset. Readings are taken on a weekly basis and monitoring commenced on the 9th August 2006.

Plate 3: Jurassic Towers

2.7.1.1 MONITORING WITHIN JURASSIC TOWERS RESULTS

A graph on Figure 42 displays the maximum and minimum readings for both temperature and humidity together with average of these readings.

Temperature readings through this monitoring period are constantly high, especially during the summer months, with values reaching a maximum of 29°C in Jurassic Towers. Poor ventilation and the effects of the Sun on the metal clad building keep these temperatures elevated. In contrast, the minimum (night time) temperatures are between 16-19°C, which is more acceptable for a working environment and records stored within.

During the autumn and winter months, these readings are slightly lower, with a maximum of 26.5°C. Where the minimum temperatures range from 17-12°C. The diverse ranges of temperatures during the winter months are not greatly affected by the decrease in external temperatures (Figure 5). This is surprising as the building appears to be poorly insulated. The temperatures have been kept high probably due the use of office equipment, body heat from staff and most importantly central heating.

Within Jurassic Towers the humidity readings have fluctuated dramatically with the summer highs in excess of 70% RH and minimums of 38% RH. Whilst during the winter, humidity levels reach 65% RH, and lows of 30% RH. The average during this recording period is around 45-60% RH.

The changes in humidity levels are being affected by external humidity, as similar patterns are occurring outside the building. (Figure 5) This shows the central heating and other heat sources are not helping to lower the humidity levels, which re-enforces the fact that the building is poorly insulated against summer and winter external conditions.

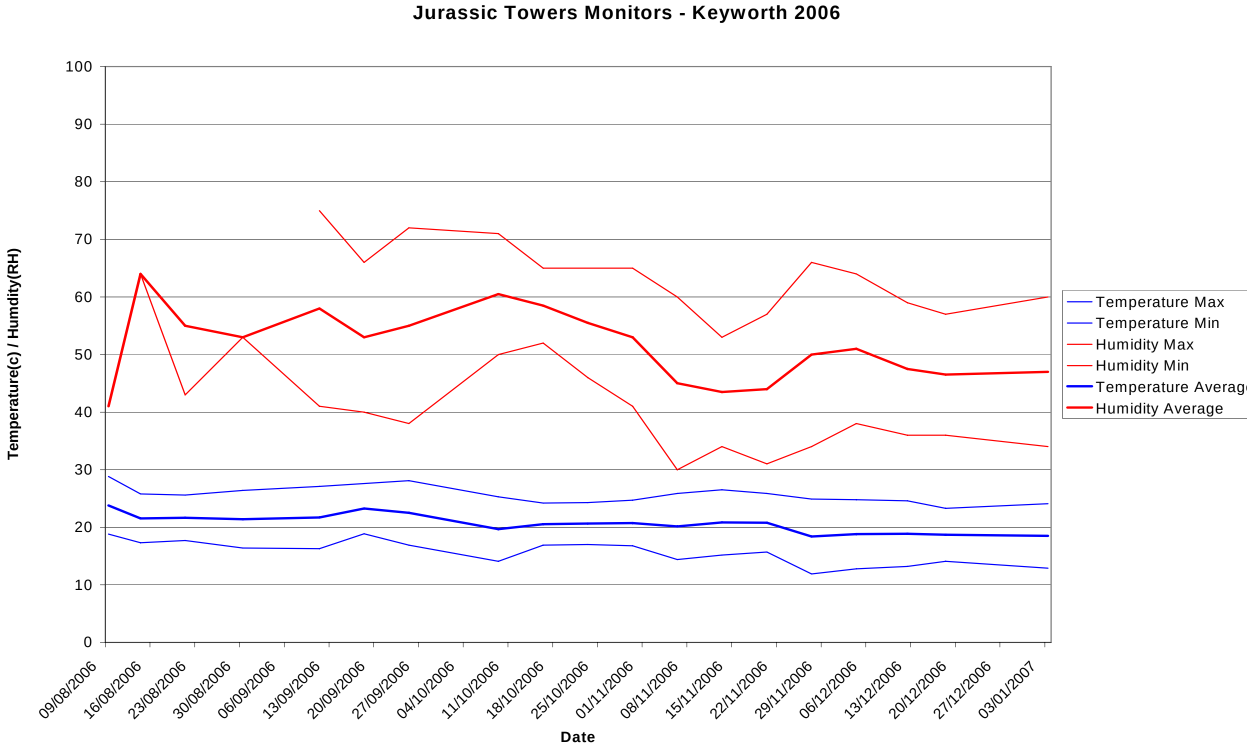

Figure 42: Temperature and humidity values within Jurassic Towers - 2006

2.8 MONITORING WITHIN THE LIBRARY STRONG ROOM 2006

Since May 2005, a new air conditioning system has been installed within the Library strong room to comply with the British Standard BS 5454:2000, which recommends for the preservation of archival documents the temperature should between 16-19°C, whilst the Relative Humidity should be between 45-60%.

2.8.1.1 MONITORING WITHIN THE LIBRARY STRONG ROOM RESULTS

A graph displaying the results for the library strong room in 2006 and 2005 is shown in Figure 43 and Figure 44 respectively.

Temperature readings are stable throughout the year and appear to be within the recommended 16-19°C, this is similar to last year's data after the air conditioning unit was installed in May 2005. However there are slight fluctuations in the temperature, caused by the air conditioning system trying to regulate the temperature to within the desired parameters. This pattern is also visible within the cold store where the temperature is regulated. See Figure 22.

During the winter months the temperature readings are towards the top of the recommended range, whilst during the long hot summer, the air conditioning system is working harder to maintain these figures; therefore, the readings recorded span a greater temperature range. External temperatures do not affect these readings.

The humidity readings at the beginning of the year show values fluctuating below the recommended 45%RH. This pattern also occurred during November-December 2005. This would suggest that the air conditioning system was not operational during these times and was only active from the end of February onwards. This was confirmed by the Library staff, who informed me that Facilities Management has turned off the system for contactors but was not turned back on.

From March to June, the humidity is often around 50% RH except for a few occasions when this peaks to 60% RH. During the summer, the readings are often over the maximum recommended range until late October. These high humidity readings could be due to the high external humidity levels, when the air conditioning system could have been struggling to maintain an acceptable pre-determined level. Incidentally, from July through to September contractors were installing new racking in the Library, adjacent to the strong room, when on occasions the strong room door would have been open for long periods, thus affecting the migration of air and humidity levels.

From November onwards; like during 2005, the humidity levels fall within the acceptable parameters, however they do fluctuate within this range. This could be when the air conditioning unit is trying to stabilize the environment after a humid period.

2.8.1.2 DISCUSSION FOR THE LIBRARY STRONG ROOM THROUGH HISTOGRAMS

Figure 45 to Figure 49 summarises the temperature and humidity within the associated recommended ranges.

The percentage of time within the recommended 16-19°C has increased by 27.7% to 75.2%. Whilst the readings outside this range have mainly occurred for values below 16°C, this equates to a 26.5% decrease compared to 2005. These improvements in the figures are also due to the air conditioning unit being operational for most of the year, compared to 2005, whilst some data was corrupt during July-August 2005, which may lower the percentage of time within the recommended range.

As with the temperature readings, the amount of time within the recommended 45-60% RH humidity range has increased to 63.2% from 39.2% in 2005. Unlike the temperature values, the amount of time above 60%RH and below 45%RH has decreased by 4.9% and 19.1% respectively.

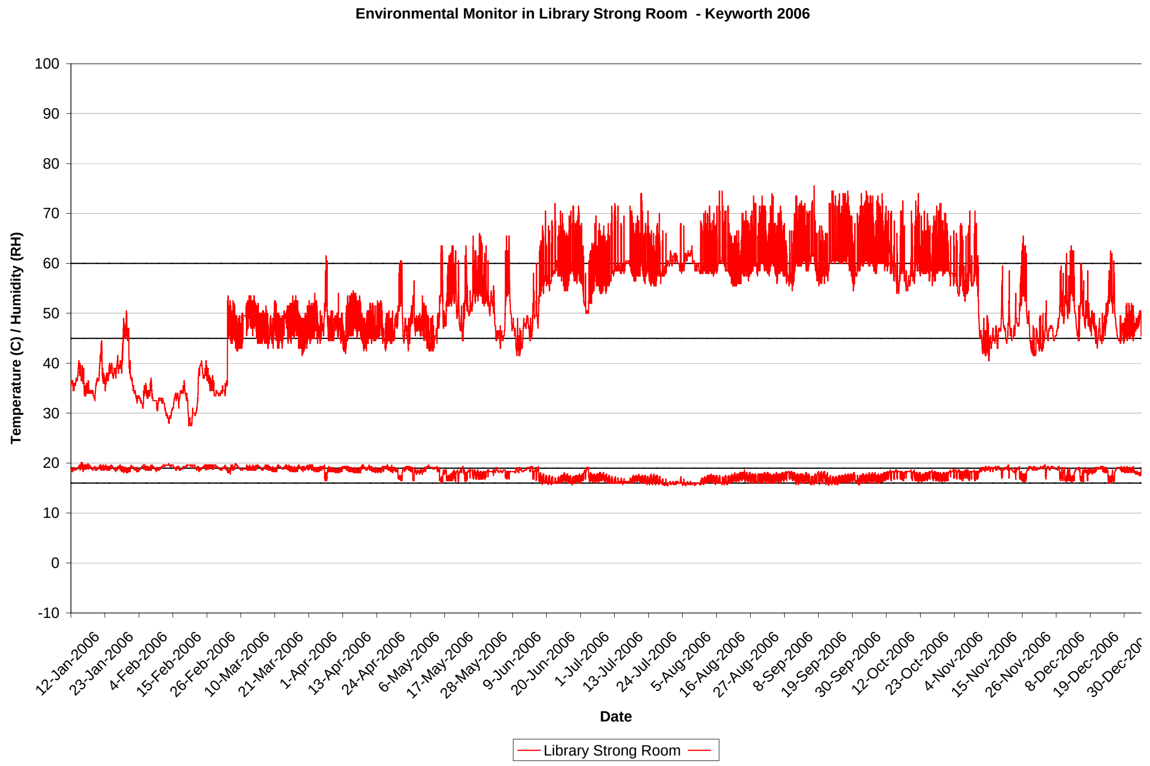

Figure 43: Temperature and humidity values within the library strong room 2006

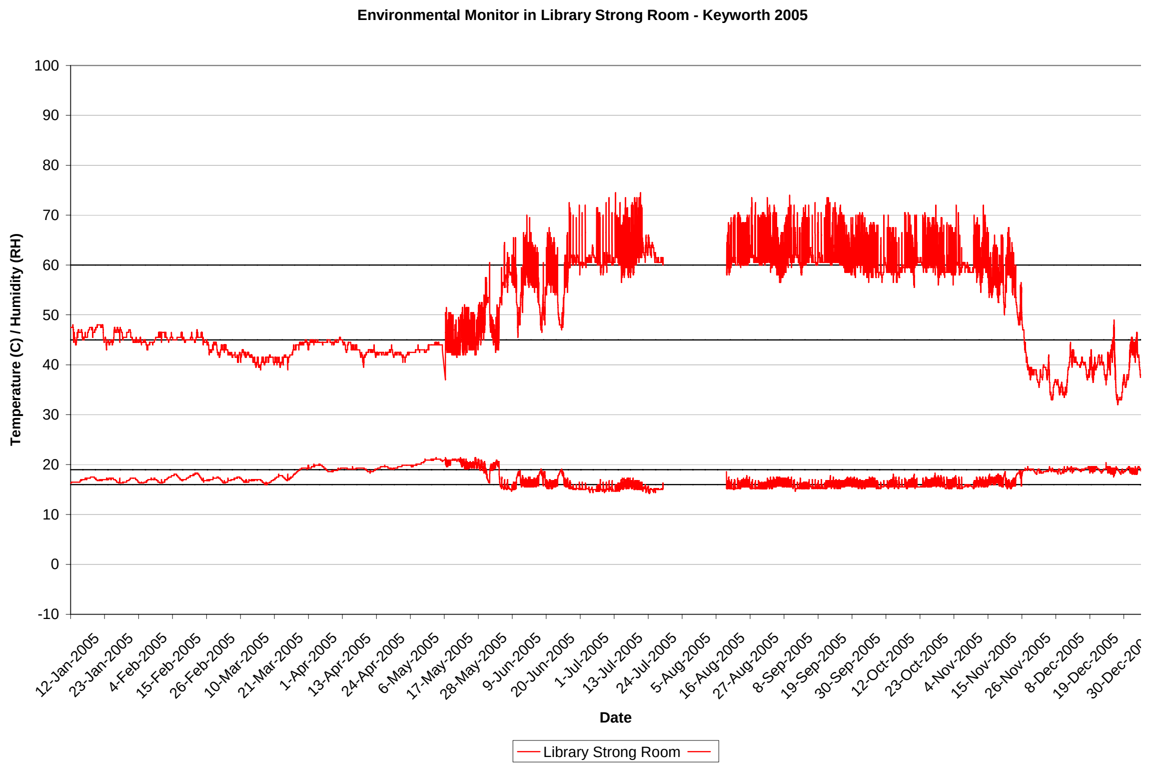

Figure 44: Temperature and humidity values within the library strong room 2005

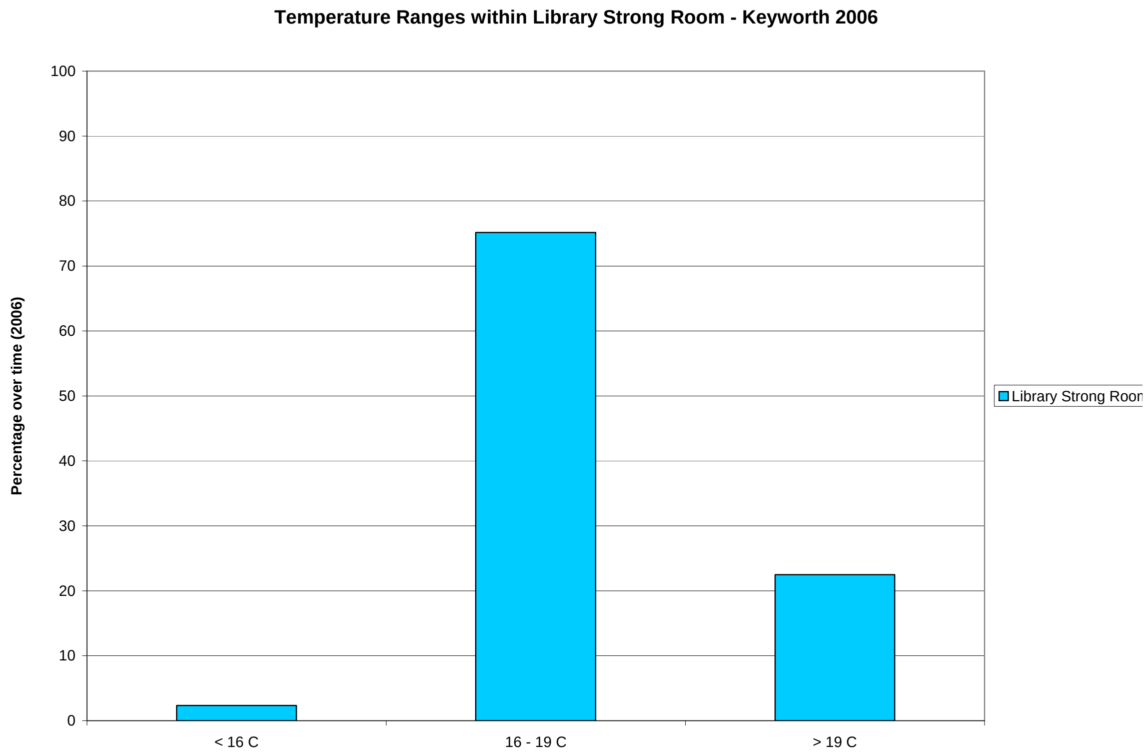

Figure 45: Histogram: Temperature ranges within the library strong room 2006

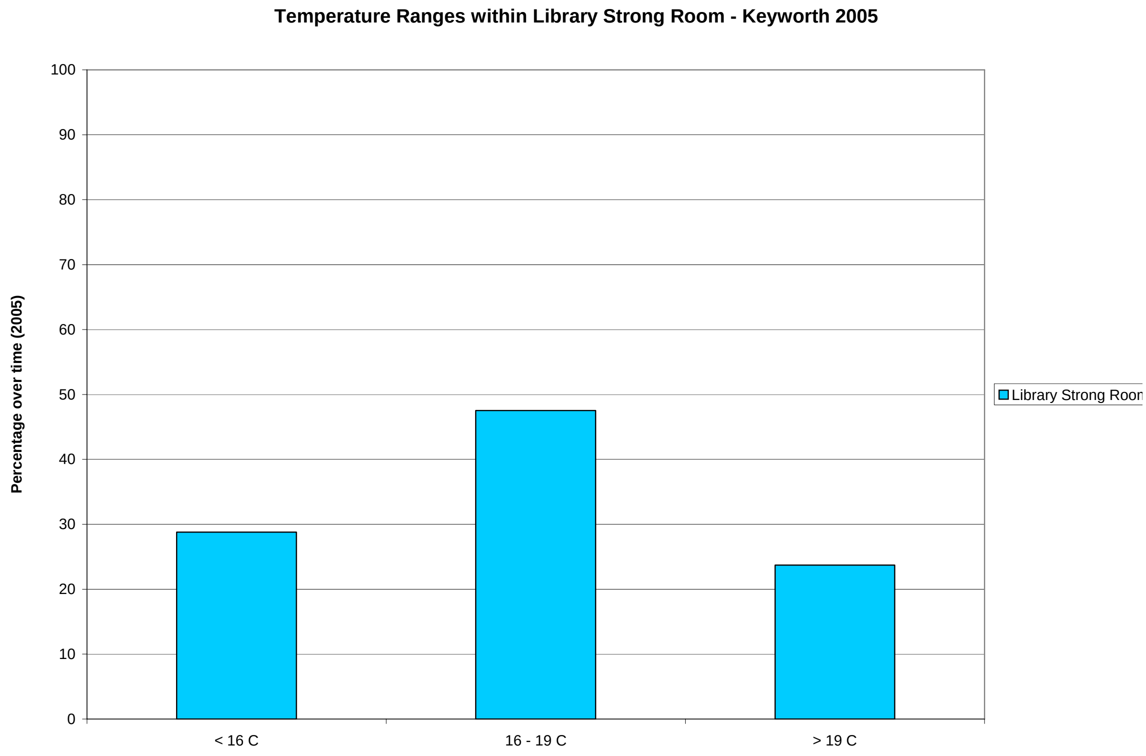

Figure 46: Histogram: Temperature ranges within the library strong room 2005

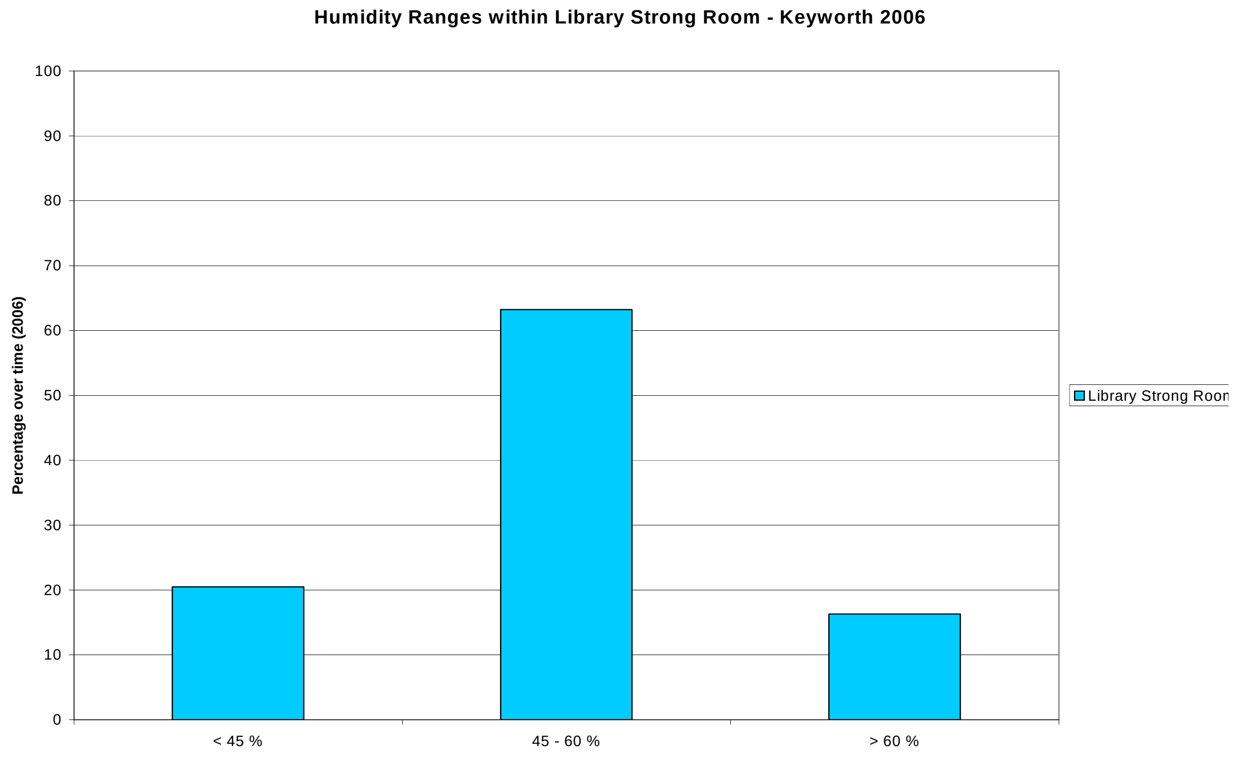

Figure 47: Histogram: Humidity ranges within the library strong room 2006

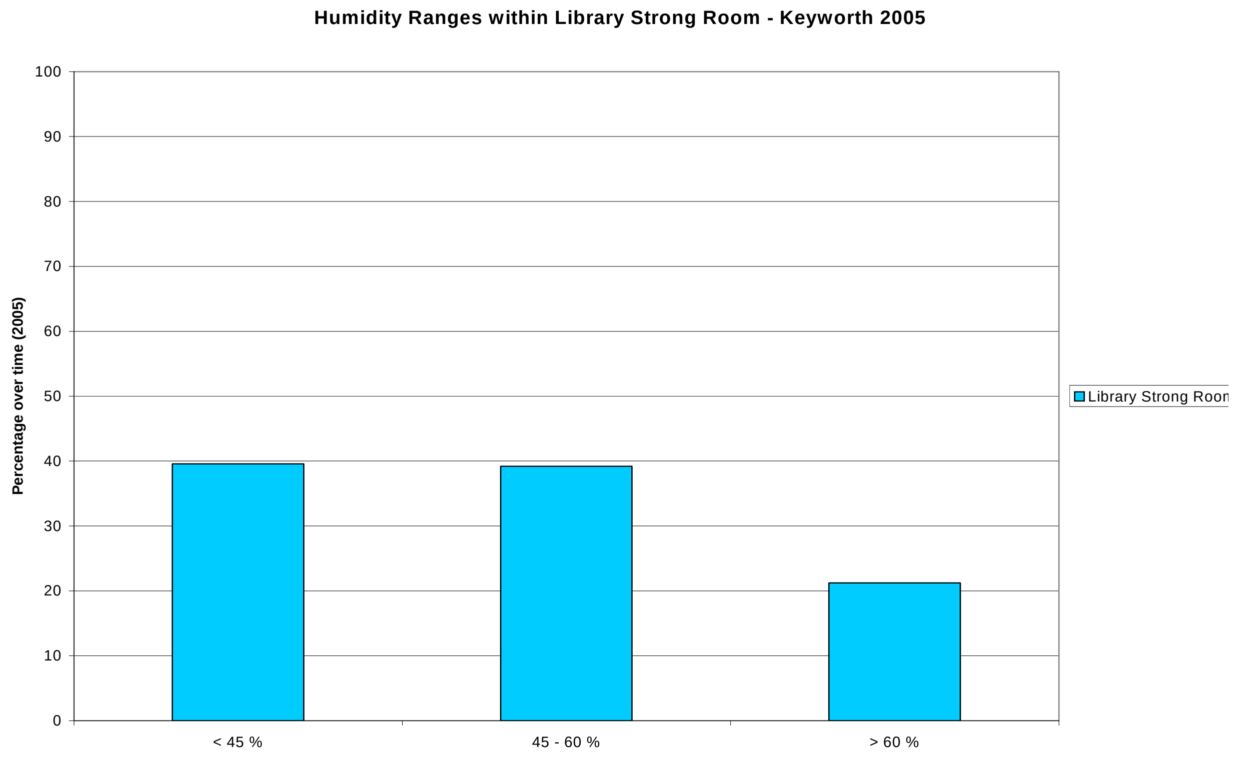

Figure 48: Histogram: Humidity ranges within the library strong room 2005

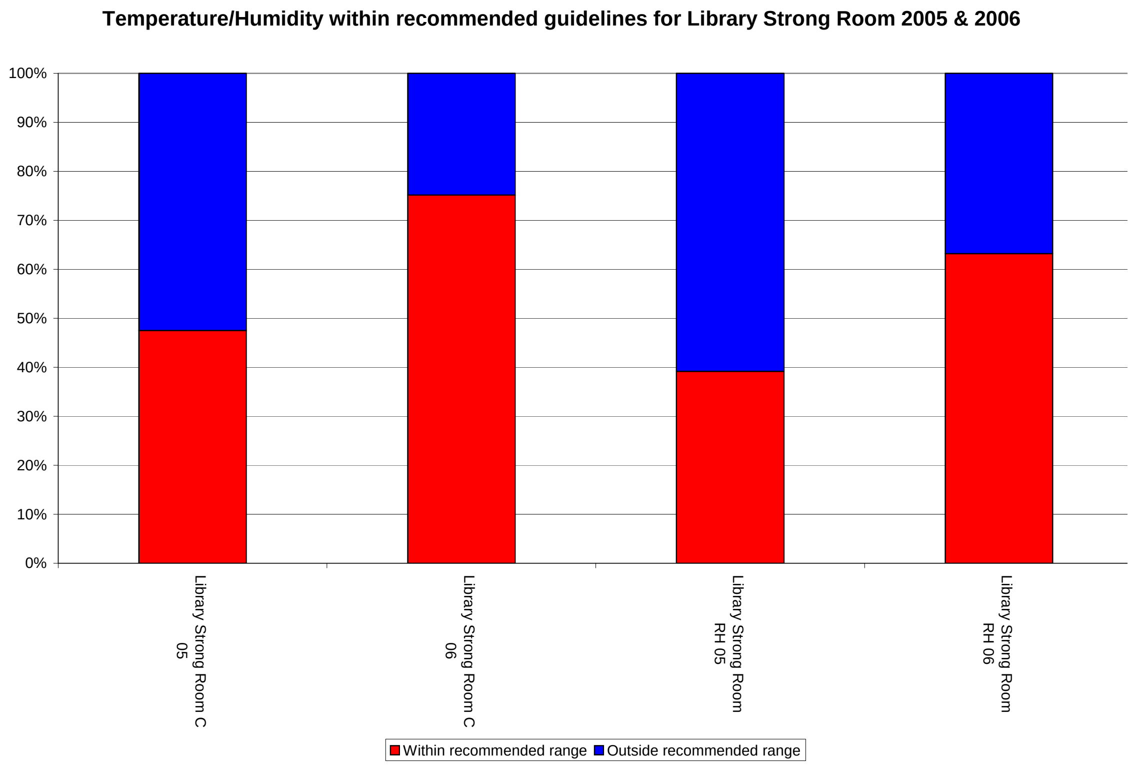

Figure 49: Temperature / Humidity within guidelines for the Library Strong Room 2005-2006

2.9 MONITORING WITHIN THE SNS SERVER ROOM 2006

BGS recognised that the scope for monitoring of environmental conditions should include all corporate digital and non-digital data and hence this must include data in BGS main computer rooms. Although this was previously done via the use of paper based chart recorders, a history of conditions is now recorded by the new air conditioning units and checked daily by SNS, with automatic high temperature alerts also sent by e-mail to SNS and Estates staff. The room is also included in the site wide environmental monitoring exercise.

The Keyworth site computer room houses more than 100 computer servers, a data storage facility with over 100 TeraBytes of on-line storage and core networking equipment. This provides a resource for projects as well as essential business functions such as e-mail, intranet and BGS web based activities. To ensure the security and integrity of data, magnetic tapes are also used to store data within the main room, as well as in a secure offsite facility.

Modern IT equipment and magnetic tapes are tolerant of a wide range of temperature and humidity conditions, but the concentration of such a large amount of heat generating equipment requires the room to be air conditioned. New air conditioning equipment was installed in March 2006 to a modular design that allows for the failure of a major component whilst still maintaining acceptable conditions in the room. Cool air is delivered to areas of the room where it is needed via grilles in a raised floor, and the units are set to an output temperature of 20.5^{o}C and a relative humidity of 35%. These conditions have proved adequate for both the equipment and staff working in the room.

Two additional Diplex digital temperature monitors have been positioned in the server room. One monitor is positioned adjacent to the main access door, whilst the other is next to the new air conditioning unit. Please note these monitors are only capable of recording temperature readings, whilst monitoring in this area commenced at the beginning of May 2006.

Plate 4: SNS Server Room (Near Door)

Plate 5: SNS Server Room (Near A/C Unit)

2.9.1.1 MONITORING WITHIN THE SNS SERVER ROOM RESULTS

The graph on Figure 50 shows the maximum, minimum and average temperature readings for both areas within the server room. External weather conditions are shown in Figure 5. Please note, these monitors have not been calibrated with the other monitors during the calibration period, therefore the values displayed might not be as accurate, but will still give an indication of the general conditions.

Temperature readings next to the air conditioning monitor are relatively constant, with average values around 21°C. There are occasions when the maximum readings for this area peak around 25°C. The first peak occurring at the end of June coincides with the second hottest period during 2006. Interestingly, the area close to the air conditioning unit isn’t being affected by the hottest months in July and August. The other peak during mid October is due to cleaners and decorators requiring access whilst working in the server room. Therefore the increases in temperature are due to higher temperatures from the corridor.

By comparison, the readings from the other monitor; close to the main door into the server room, is on average higher than the one next to the air conditioning unit. Even though this unit supplies both areas in the same room, however there is still a noticeable difference in the readings.

This monitor has recorded all of the hottest periods throughout the summer, with values reaching in excess of 26°C. This shows that warmer air from the adjacent corridor is affecting the temperature, when the door to the server room is used. Similarly, maintenance work carried out during October, shows periods of higher readings than the monitor next to the air conditioning unit. Additionally, a period of cooler temperatures in October is due to the central heating being turned off in adjacent rooms at the weekends, whilst access to the server room was required.

The corridor and other rooms, adjacent to the server room door, are affecting the temperature readings, whereas areas close to the air conditioning unit show better-regulated temperatures. However, prolonged access to the server room does affect the temperature readings in both areas to some extent.

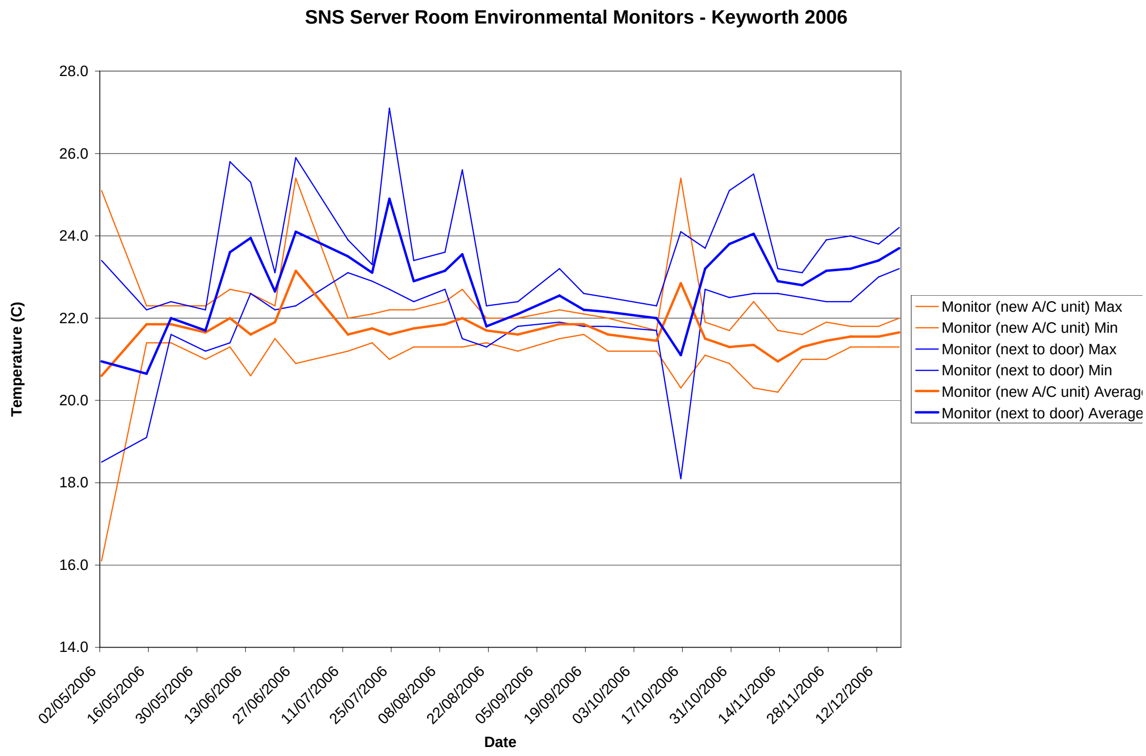

Figure 50: Temperature values within SNS Server Room - 2006

2.10 2004 RECOMMENDATIONS ACHIVED DURING 2005 FOR KEYWORTH

Based on last years report *Shepherd & Tulloch, 2005*, the following recommendations have been achieved during 2006.

2.10.1 General monitoring

Monitoring has continued throughout the year for all existing main areas. Certain zones that had partial data during 2005, such as the monitor on the first floor within a mahogany cabinet and the Library strong room, now have full data to be used for comparative purposes.

New monitors have been positioned where continual data was not previously available; this includes a wall cabinet on the ground floor of the museum containing sub-fossil bone material, one monitor within Jurassic Towers, and two monitors in the SNS server room.

Calibration of all monitors continues on an annual basis.

The monitor in the Stevenson Screen during 2005 has been relocated to a wall cabinet in the museum containing sub-fossil bone.

The Thermohygrograph in the museum was decommissioned during May 2006.

2.10.2 Core store

The trial experiment of placing a beaker of water within the Conservation Laboratory has been re-run during 2006, to try and increase humidity at certain times of the year.

The ceiling extractor fans and air circulation units are now regulated by the Core Store Manager via Facilities Management when required rather than being turned on and off at regular times of the year. Therefore more control in maintaining regular temperatures within the core store may be achieved.

2.10.3 Museum

The deep clean that commenced during 2005 of the museum cabinets and drawers has now been completed. This has reduced the amount of dust within the museum and improved the visual appearance of the specimens. Additionally problematic areas within the collections were brought to the attention of the Museum Staff and Conservator.

The trail humidity experiment in the Conservation Laboratory has now been implemented for the larger sub-fossil bone specimens, to try and prevent periods of low humidity occurring.

An additional monitor has been positioned within a wall cabinet on the ground floor, containing sub-fossil bone material, so comparisons can be made between material inside and outside of the wall cabinets.

The Conservator carries out a systematic condition surveys on a regular basis to assess the condition of the collections.

Contractors have instigated the installation of a security swipe card system on the entrance doors to the museum; however this is not yet operational. This will improve the security into the museum, whilst helping to minimise the effects of temperatures and humidity levels from adjacent corridors.

Numerous museum cabinet doors were not locking properly. Facilities Management were informed and the BGS carpenter has now altered these accordingly. This now provides a more secure and better-protected environment for the specimens.

2.10.4 NGRC

Exposed central heating pipes were lagged during November to try and stabilize the temperature within the records room and to making heating the room more efficient.

Data is sent to the relevant area manager on a weekly basis, to allow the continual assessment of the information collected.

2.10.5 Jurassic Towers

Monitoring within this area commenced during August 2006.

Data is sent to the relevant area manager on a weekly basis, to allow the continual assessment of the information collected.

2.10.6 Library Strong Room

Weekly data from the monologger within the strong room is sent to Library staff for comparison with the British Standard BS 5454:2000.

2.10.7 SNS Server Room

Monitoring within this area has commenced during May 2006, with data being sent to SNS staff on a weekly basis for comparison.

The installation of an air conditioning system within the server room has been undertaken.

2.10.8 Miscellaneous Areas

The monitor positioned within the Stevenson Screen during 2005 has been removed, as readings were inaccurate following periods of high humidity or morning dew on the sensors. The traditional thermometers in the weather station are now being used instead.

Previous implemented recommendations on usage patterns within storage areas are continually being honoured. These include the closure and now locking of museum cabinet doors, the closing of window blinds, and the closing of shutter doors within the core store whenever possible.

2.11 RECOMMENDATIONS FOR KEYWORTH 2007

2.11.1 General Monitoring

- Monitoring must continue for all the areas reported on within 2006, so that we can continually assess the effects that temperature and humidity are having on the collections.
- Data should be sent to the relevant area manager on a weekly basis, to allow them to make an assessment of the information collected and to inform Facilities Management of any necessary changes they think may be required.
- Calibration of the monitors should continue on a regular basis throughout the year, where new monitors can be used as benchmarks during the calibration period.
- When additional funding becomes available new monitors should be purchased. This would enable us to collect data from new locations and any problematic areas, which may need investigating further, via a mini project.

- To instigate an electronic calendar via a shared network drive, so all area managers can record details of any changes or irregularities in working practices that may have caused anomalies in the data sets throughout the year.

2.11.2 Core Store Areas

- Data to be sent to the core store manager on a weekly basis to provide additional information for the effective use of the ceiling fans and air blown systems to regulate the high summer temperatures.
- Minimise the use of the shutter doors at the rear of the core store wherever feasibly possible, thus allowing for a more stable environment within surrounding locations.

2.11.3 Museum Areas

- Continue to run the humidity experiment adjacent to the sub-fossil bone material so comparisons can be made between suitable storage areas for this material.
- If possible with guidance and approval from the Conservator, set-up a microclimate in the wall cabinet containing the sub fossil bone material.

2.11.4 NGRC Areas

- To assess if lagging the central heating pipes has stabilized the temperature especially during the spring when weekly cycle patterns occur.
- The use of temporary portable humidifiers to increase the humidity during colder periods, even within the strong room, until a permanent environmental control system is installed within the NGRC. This would be beneficial at improving the environment which is presently causing some concern.
- To keep all window blinds shut where possible to reduce the effects of solar gain within the records room, until suitable replacement blinds are installed.
- Thermostatic controls on the current heating system should be used to lower temperatures within the records room, as they are presently too high.

2.11.5 Jurassic Towers

- It is essential that monitoring continues throughout 2007, so a full annual data set can be collated. Then measures can be taken to resolve the high temperatures experienced in this area.

2.11.6 Library Strong Room

- Continual monitoring of the strong room is essential to assess the effectiveness of the new air conditioning system, thus allowing any adjustments to be made in order to improve the conditions within the strong room.

2.11.7 SNS Server Room

- Monitoring must continue with the assessment of the new air conditioning system used to regulate temperature and humidity within the server room.

2.11.8 Other Areas

- To continually asses the effectiveness of new air conditioning systems within the Library strong room and SNS server room. This would also enable us to look at the possibilities of using similar systems in areas that are currently not providing acceptable conditions for the type of materials stored there, such as the NGRC.

3 Monitoring at Edinburgh

A maximum of ten Digitron loggers have used to gather internal temperature and humidity data in Murchison House. For the first 5 months of 2006 there were three in the Palaeontological storeroom, three in the Petrological store and three others, including a 'mobile unit', in the Archive Store housing non-geological material, mainly paper records and reports, see Figure 51 & Figure 52.

An additional system, located on the northwest roof of Murchison House, is used to capture weather statistics. This unit monitors wind speed & direction, temperature, humidity and rainfall. These data are uploaded to a networked computer and can be interrogated in real-time or the data downloaded to a local pc in daily files.

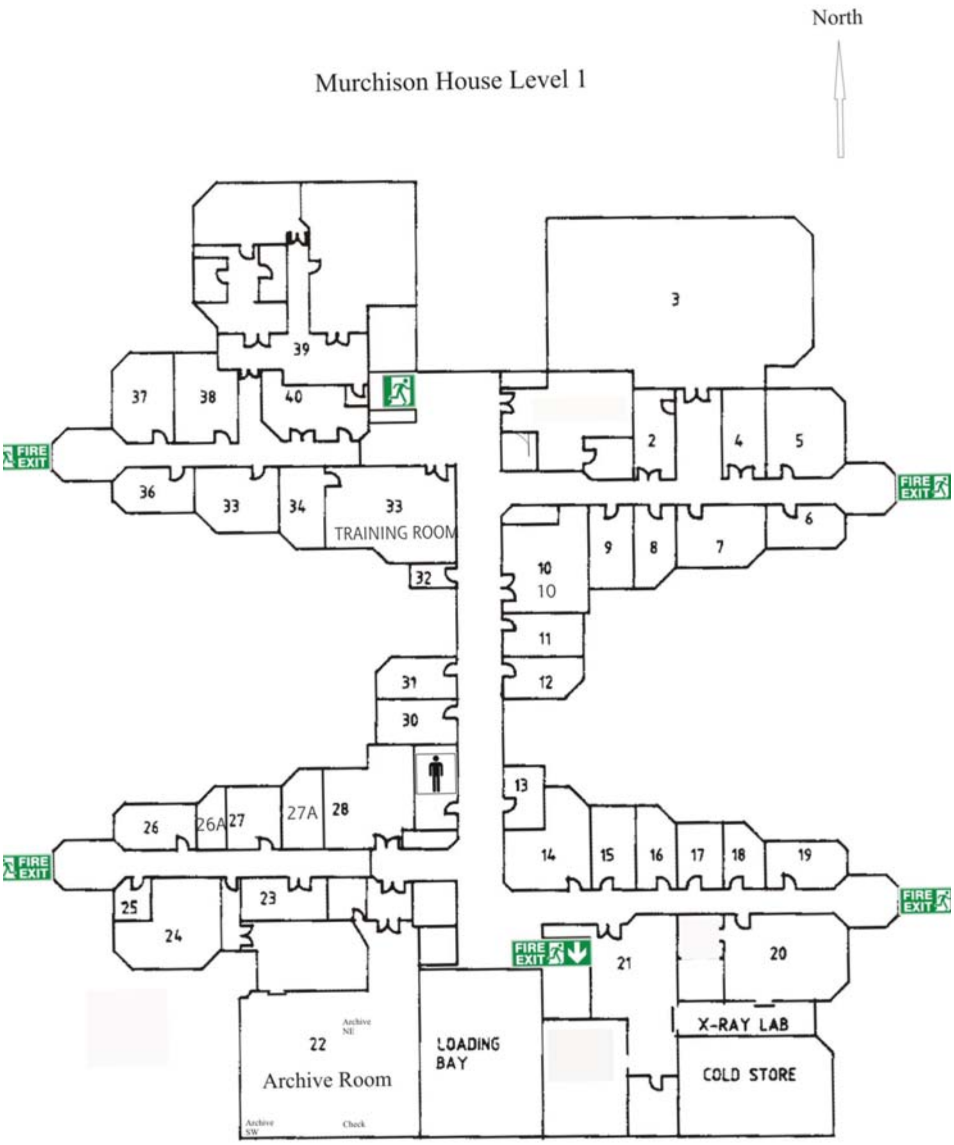

Figure 51: Location of Murchison House loggers: Level 1, Archive Room

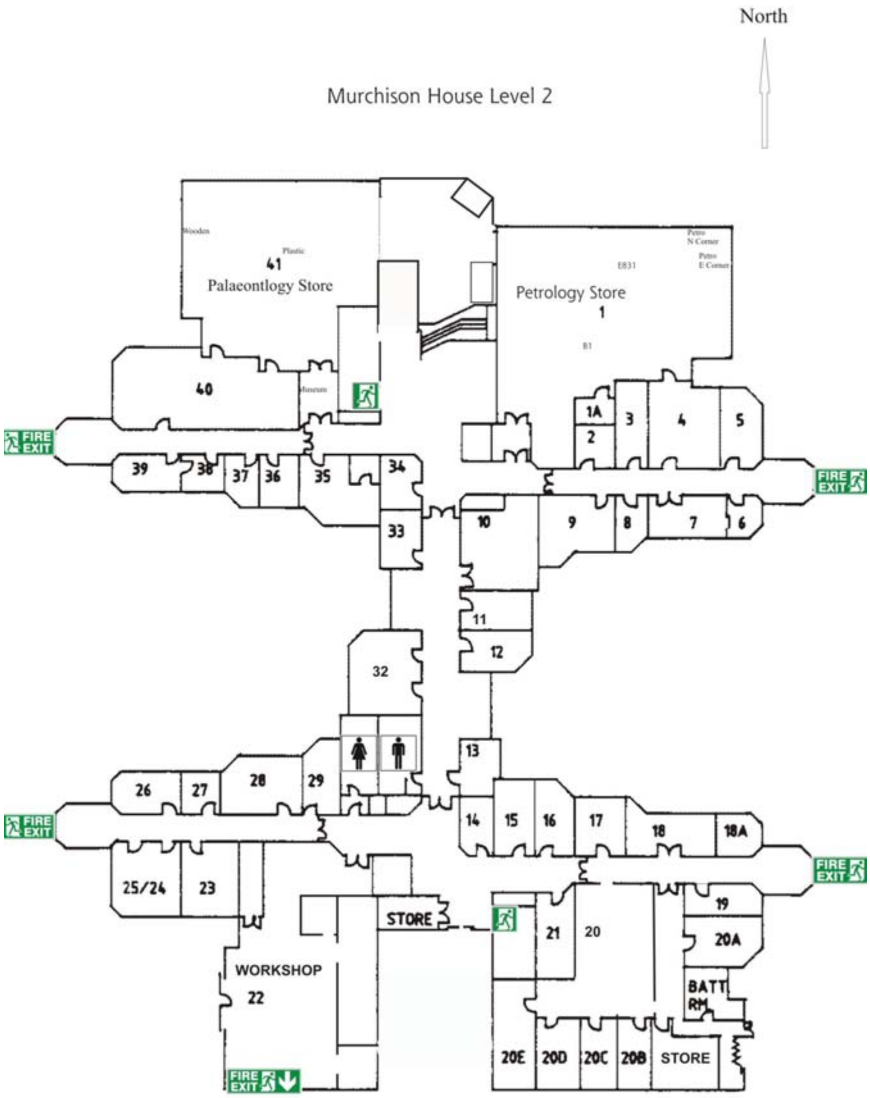

Figure 52: Location of Murchison House loggers: Level 2

There have been a number of problems with the loggers throughout the year, resulting in some being removed from established sites to replace defective units in others.

Reacting to colleagues concerns, we have expanded monitoring locations in Murchison House to include the computer server room and the library storeroom.

Loggers from the Petrology storeroom B1, NE and E Corners have been removed, as has the Archive Check. Loggers from the B1 and E Corner positions were relocated in the Server Room and Library respectively.

Following a visit by TNA (The National Archives) in November 2005 it was decided the two stores should be monitored to collect analytical environmental data. Loanhead was monitored for a short period in 1999: it is known that the conditions are poor. However, as Gilmerton was only recently acquired by BGS there is no data for that store. Eight new loggers were purchased to monitor these stores.

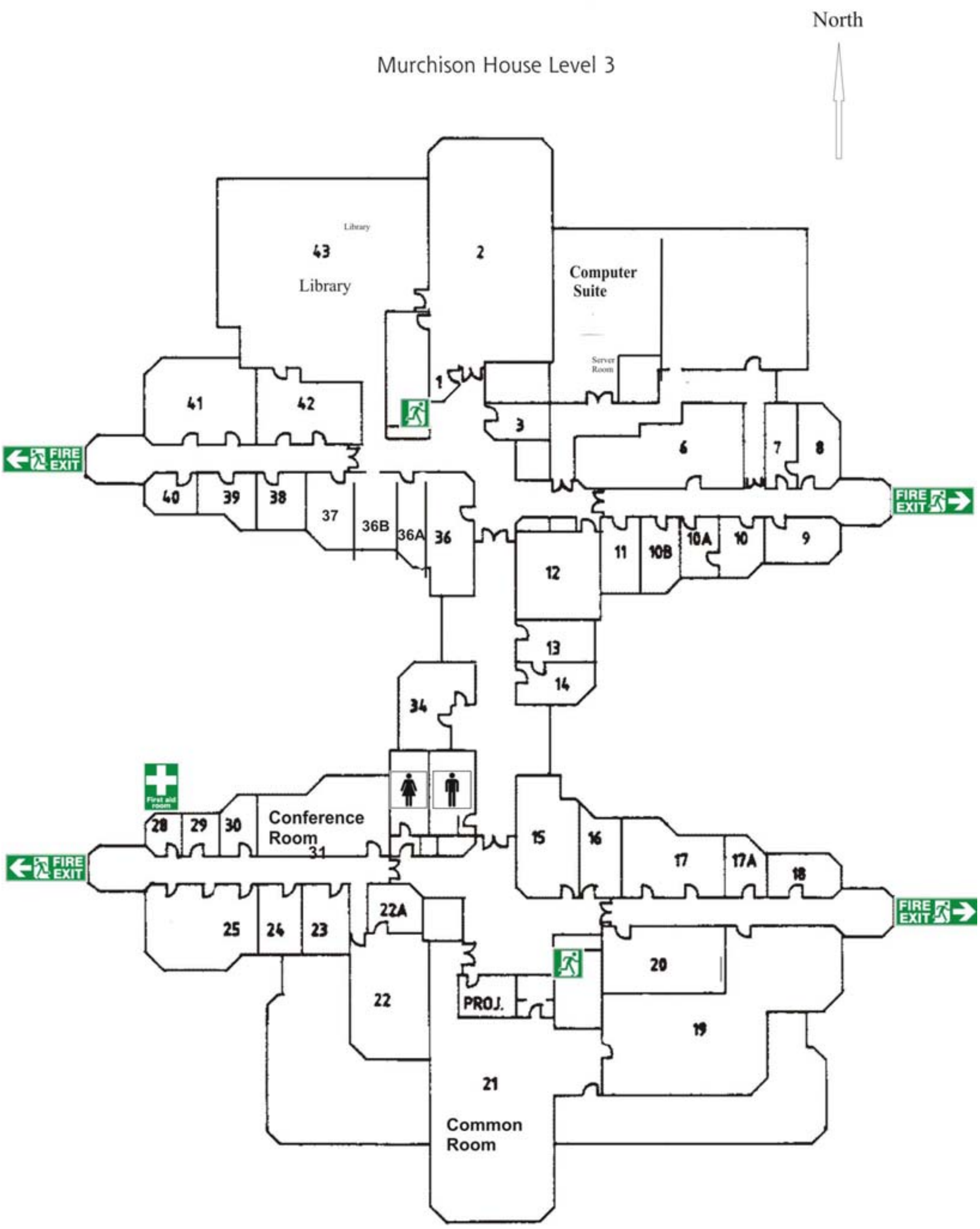

Figure 53: Location of Murchison House loggers: Level 3

It is recognised that these loggers are in location for recording purposes only as there is no equipment installed in either of the stores to control the environment other than to maintain an above-dew point and frost-free temperatures.

The “Archive Check” logger has been moved to an office at Loanhead and an additional instrument installed by Facilities Management placed in another, although the data from these loggers is not discussed in this report this bring the total of different locations in BGS’s Edinburgh facilities we are currently monitoring to 18.

To compensate for the removal of the continuous recording logger’s, small maximum/minimum units have been purchased and are read and zeroed at the same time as the others are downloaded.

Murchison House internal data is downloaded every Tuesday (to avoid Monday holidays) at approximately 10am. By downloading on the same day and time every week errors or sampling artefacts can be easily identified.

Data are saved to logger compact file format, readable only with the propriety software supplied with the instruments, and have the extension lcf. These are the master files.

The files are converted into MSExcel format and imported to an MSAccess database. All data are recorded in GMT and require no alteration from BST

The Excel spreadsheets labelled "MH 30 Minutes 2005.xls" and "MH 30 Minutes 2006.xls" contain data for 2005 and 2006 extracted from an MSAccess database in which all data is stored. It is from these files that the annual graphs are produced.

As with the core stores, the Library does not have any air conditioning equipment installed within the store and the environment cannot be affected: by comparison the Server Room has two units maintaining an appropriate environment for the equipment.

Data from the Library and Server Room are recorded at 30 minute intervals, this allows a download to take place every 4 weeks. The data from the two locations are appended into one excel spreadsheet and added to the Murchison House Access data base for storage and extraction.

Data from the Weather Station are uploaded automatically on to a remote computer and downloaded in daily ASCII files with extensions identifying the content (.MHU, .MTA, .MWD, .MWS, .PP designating Murchison House Humidity, Temperature, Wind Direction, Wind Speed & Rainfall resp.).

The Excel spreadsheet labelled “Met data 2006.xls” contains all available Weather Station data for 2006 in 30-minute intervals. It is from this file that the external data graph is produced.

3.1 CALIBRATION

When purchased, the loggers are guaranteed for accuracy of +/-0.3^{o}C with an average resolution of +/-0.3^{o}C. The units are placed in the same specimen tray for at least 24 hours; this allows them to be calibrated to the one unit, providing better data for comparison. During 2006 all the loggers were calibrated in this way at least once during 2006, in February. The main ‘core’ loggers were also calibrated in June; others were calibrated as they were taken out and in of service.

3.1.1 Calibration Method

The loggers were placed in an empty plastic specimen tray overnight for a period of 24-hours. The calibration is undertaken partway through a weekly monitoring period to allow any changes in readings to be more easily determined. At the end of the 24 hour period the loggers are returned to their usual locations and the data downloaded and graphed at the normal time the following Tuesday.

It is recognised that this may not be the most accurate method of calibration, however, new loggers are guaranteed to be very accurate, as discussed above, and the technique chosen is similar to one of the manufacturers own methods.

3.1.2 Calibration Discussion

An excel macro is utilised to calibrate the loggers. Estimations are made to add or subtract values from the data recovered until the traces of all the loggers converged on that of the ‘benchmark’ instrument. The data recovered from the calibration period showed that only one of the temperature values required a little alteration whereas all the humidity values were adjusted by varying amounts.

Loggers purchased to monitor the Loanhead and Gilmerton core stores were received at the end of 2005; when they were calibrated as described above the differences from the benchmark were found to be too variable to be acceptable, Figure 54. Although it would have been able to apply calibration factors to remove these variances the decision to return the loggers for recalibration was taken. This was done and the units were returned in January, satisfactorily calibrated Figure 60.

As can be seen in Table 4 below, the changes in calibration figures are, generally, very small but the associated graphs shows that even these small changes make the data more accurate.

Figure 55, Figure 57 & Figure 59below illustrate the offset when the loggers were placed in the same location but do not have the calibration factor applied.

The offset is not large; however the results are made more accurate by applying the calibration factor. The benchmark used continues to be the monitor for the Plastic tray, the green line on the graph. Figure 56, Figure 58 & Figure 60 are the same data that has had the calibration factors applied.

The results obtained from the test periods were sufficient to appease any concerns that there were large-scale problems with the rationale or assumptions behind the test and illustrates that the data acquired from the loggers are relatively constant: by calibrating the loggers every 6 months or so the small amount of 'creep' is removed before it becomes an issue.

This has been particularly useful when the data from the Archive Room was analysed. As will be discussed in a later chapter the data has shown some inadequacies with the newly installed air conditioning unit. The graphed data gave Facilities Management evidence of the problems to show maintenance engineers when they asked for the system to be inspected.

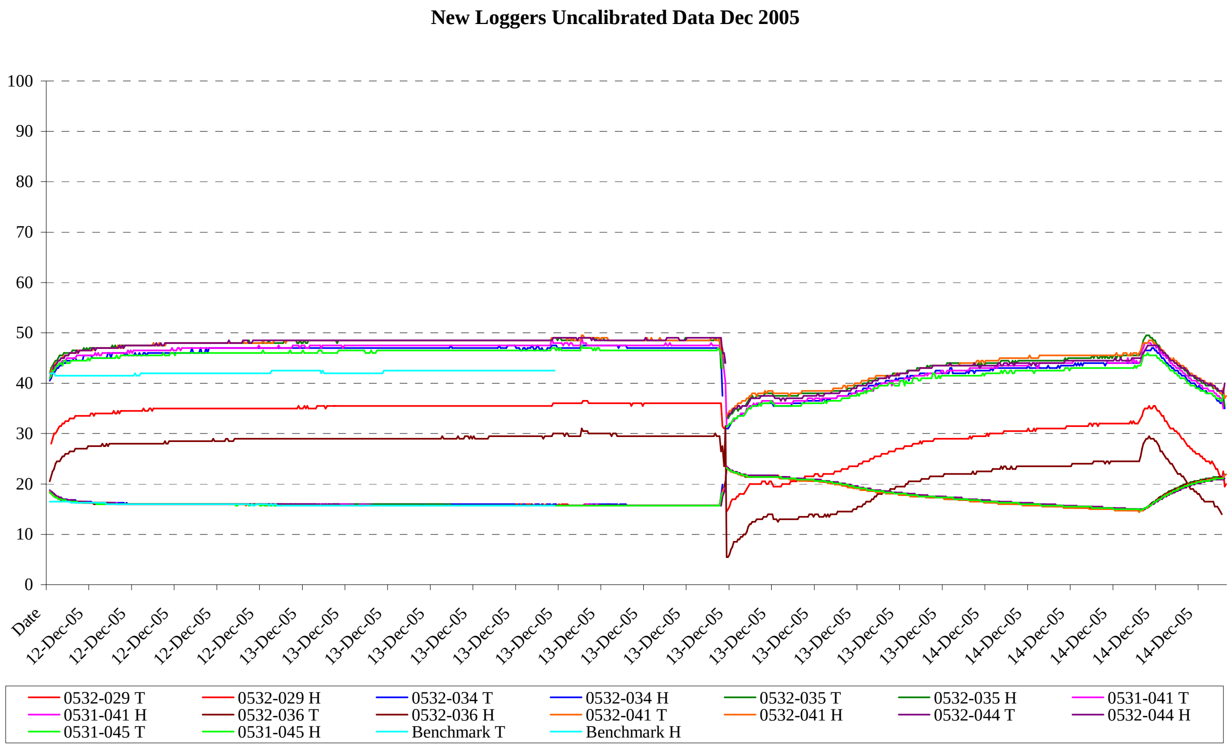

Figure 54: New Loggers Uncalibrated data – December 2005

	January		February		June	
Logger	**Temperature**	**Humidity**	**Temperature**	**Humidity**	**Temperature**	**Humidity**
Museum			-0.2	+0.5	-0.2	Same
Wooden			Same	+1.0	Same	+1.0
Plastic			Base	Base	Base	Base
E831			Same	-2.0	Same	-2.0
B1			Same	+1.0	Same	+1.0
N Corner			Same	-3.5	Same	
E Corner			Same	-5.5	Same	-5.5
Entrance/ Check			Same	-1.5		
Archive NE			Same	-1.5	Same	-3.0
Archive SW			Same	-2.0	Same	-3.0
Loanhead 1	Same	-4.5				
Loanhead 2	Same	-2.5				
Loanhead 3	Same	-4				
Loanhead 4	Same	-5				
Gilmerton 1	Same	-4				
Gilmerton 2	Same	-4.5				
Gilmerton 3	Same	-4				
Gilmerton 4	Same	-3.5				
Server Room						
Library						

Table 4: Calibration Values, Edinburgh Digitron Loggers

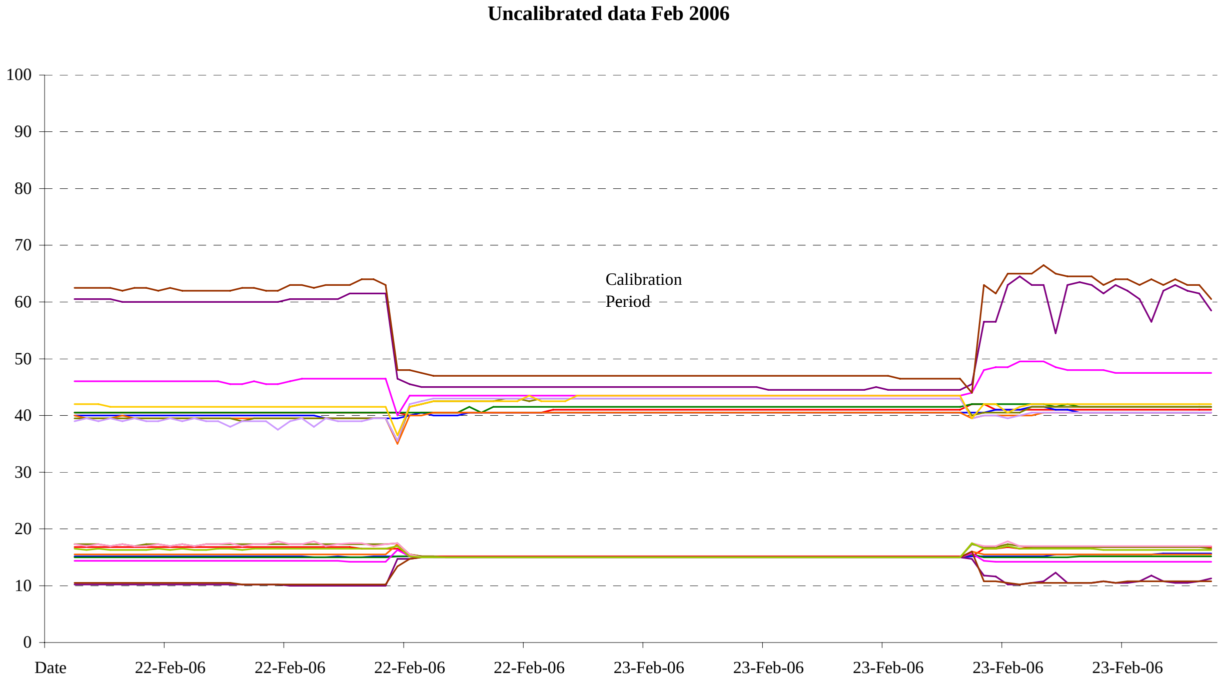

Figure 55: Uncalibrated data – February 2006 test period, Murchison House

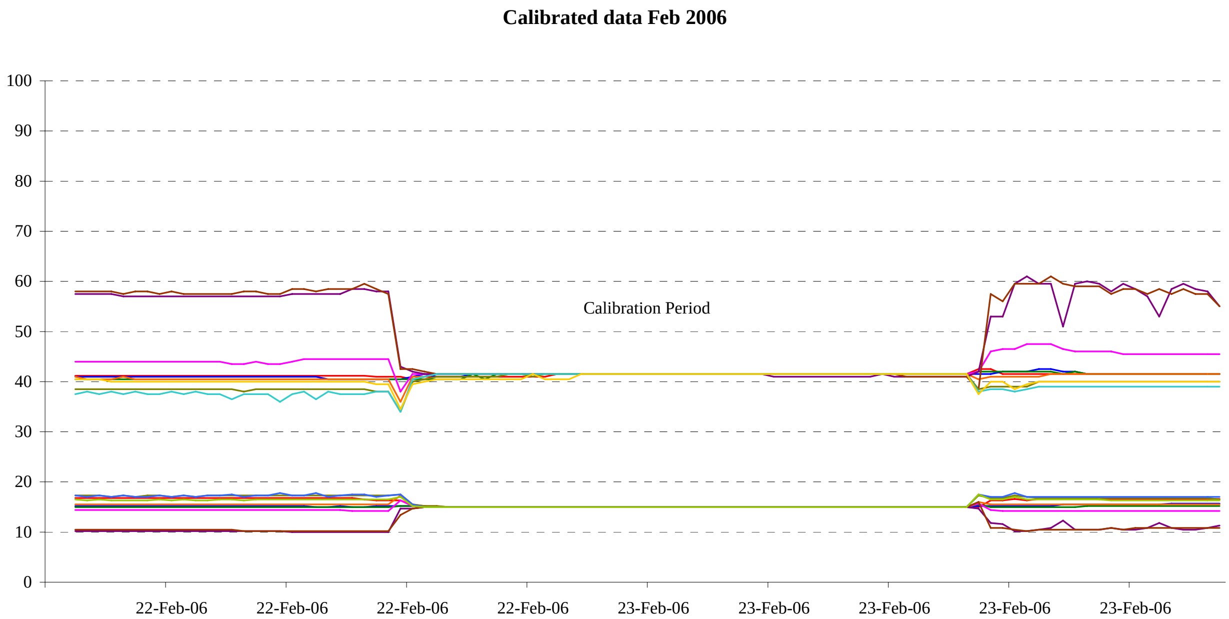

Figure 56: Calibrated data – February 2006 test period, Murchison House

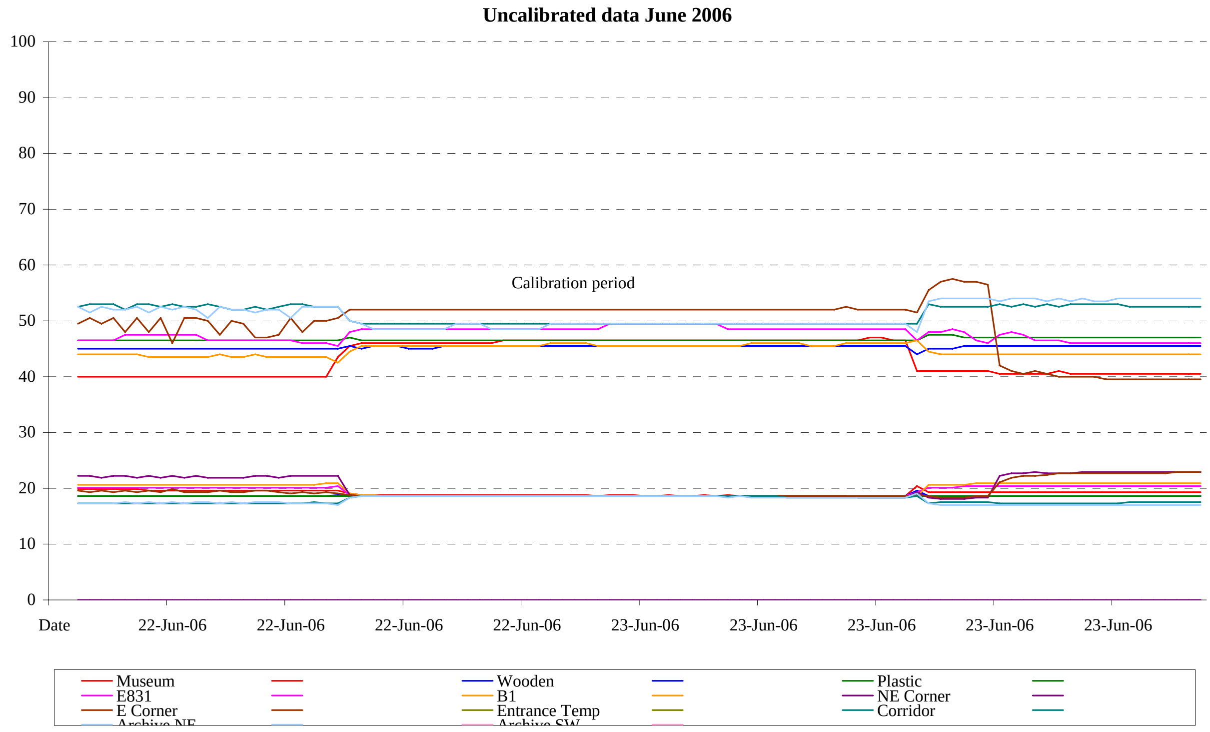

Figure 57: Uncalibrated data – June 2006 test period, Murchison House

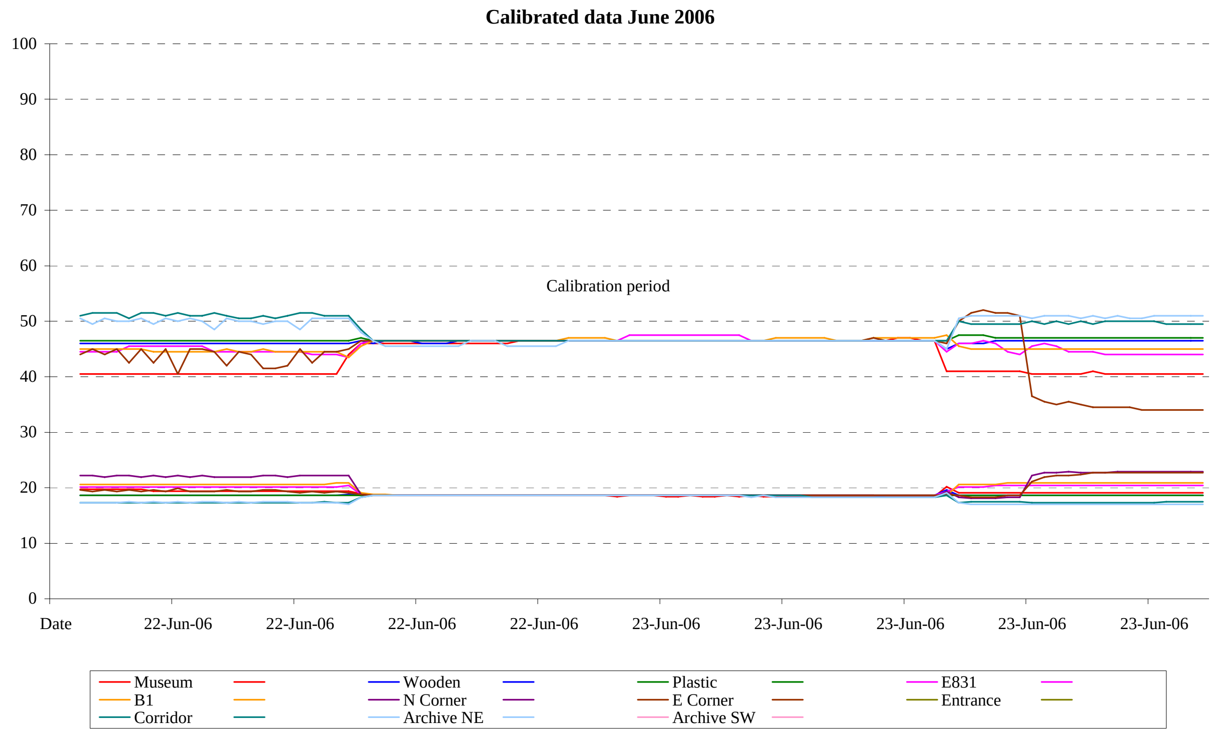

Figure 58: Calibrated data – June 2006 test period, Murchison House

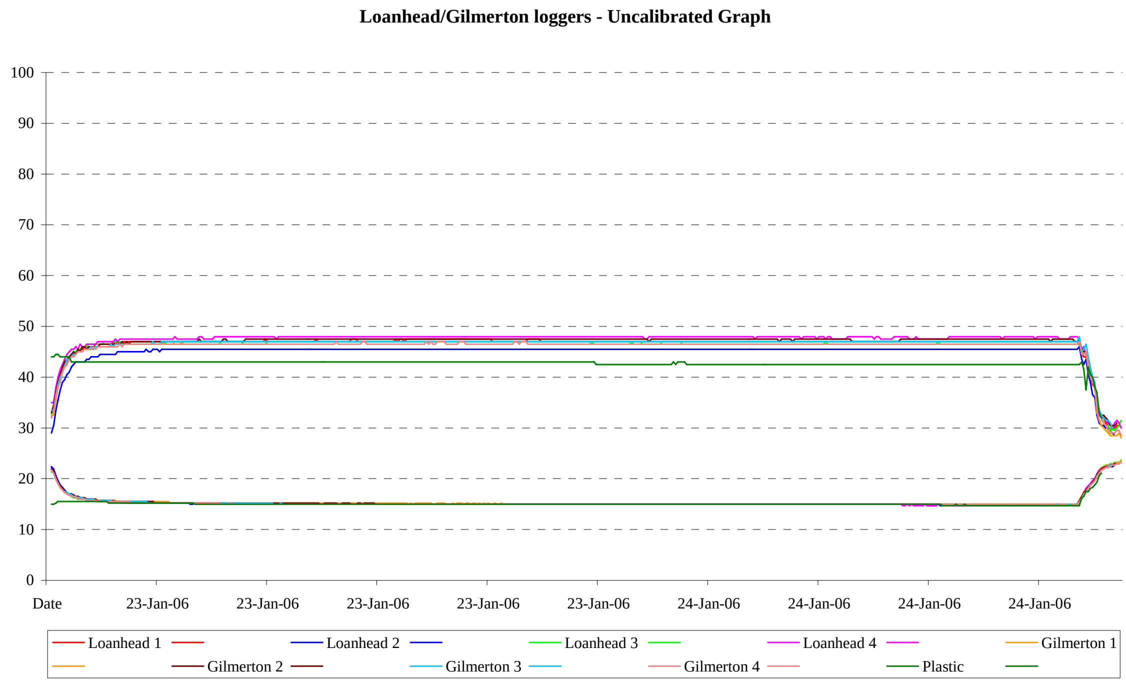

Figure 59: Loanhead/Gilmerton loggers - Uncalibrated data – January 2006

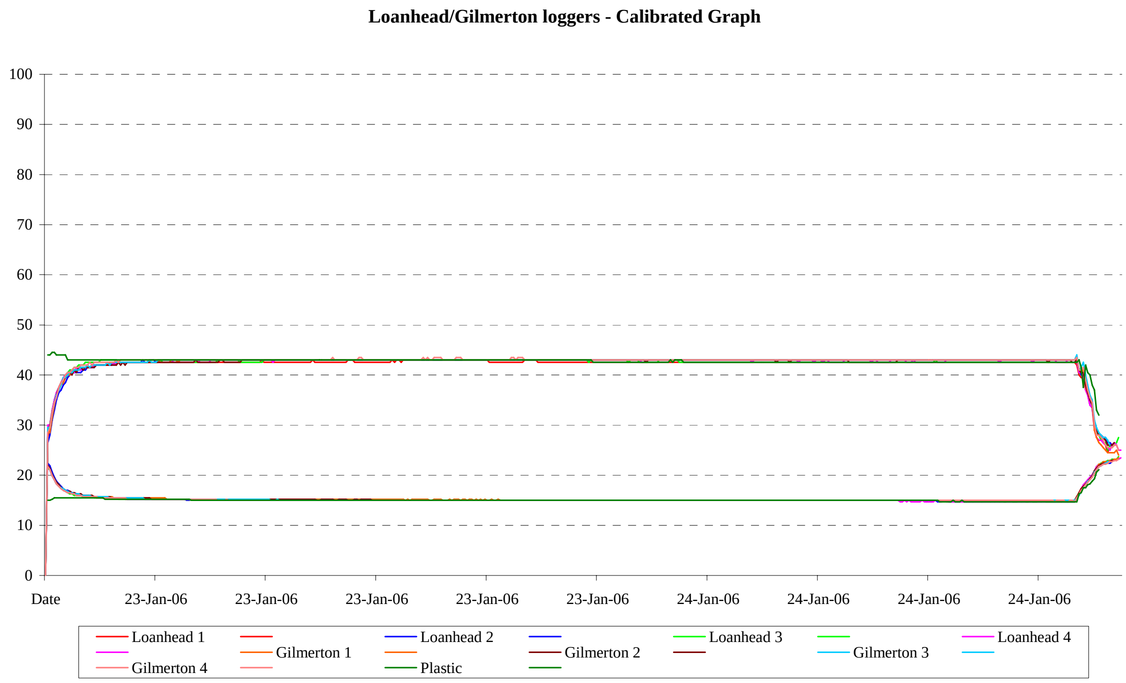

Figure 60: Loanhead/Gilmerton loggers - Calibrated data – January 2006

3.2 MURCHISON HOUSE ANNUAL DATA 2006

A total of eight Digitron loggers are now used to gather temperature and humidity data in Murchison House, three in the Palaeontological storeroom, one in the Petrological store, two in the Archive Store and one each in the Computer server room and the Library store room.

An additional system, located on the northwest roof of Murchison House, is used to capture weather statistics. This unit monitors wind speed & direction, temperature, humidity and rainfall. These data are uploaded to a networked computer and can be interrogated in real-time or the data downloaded to a local pc in daily files.

Two loggers in the Palaeontological area are in trays in the general store and the other in a Museum cabinet. Only one of the monitors that were in the Petrology store in previous years remain, E831, the other two having been removed to cover other areas. Two max/min units have replaced the loggers removed, B1 and the corner loggers.

There were a number of non-critical problems with the established loggers in 2006. A few instruments have required attention which resulted in lost data for short periods, one has lost the ability to record humidity and two borrowed units were removed to offices at Loanhead in June. However by reassigning loggers we have been able to maintain good coverage of all areas.

As discussed in previous chapters the data presented in this chapter have been calibrated to take variations in the accuracy of individual loggers into account. All times quoted are in Greenwich Mean Time (GMT).

3.2.1 Annual Data Discussion

Figure 61 shows a decline in the conditions in the storerooms in the calendar year 2006 compared to the previous 12 months; Figure 62.

When comparing the two graphs we can observe similar seasonal variations for 2006 as 2005. Both the temperature & humidity curves show seasonal variations although for 2006 the humidity is raised compared to 2005. Perhaps surprisingly, given that 2006 was the hottest summer on record, the temperatures all show a slight decrease within the target range.

The 2006 temperatures remained within the upper half of the range from approximately June until September with the months preceding and following also within range, but at the lower end. This pattern can also be seen in the 2005 graph. Although there were periods of lower temperature the readings in 2005 they did not drop out of range and so do not affect the overall result for the year.

The graphs show the expected seasonal trends of increasing temperature and humidity as the year progresses towards late summer when they begin to lessen as autumn and winter approach. The humidity generally follows this trend, although in 2006 it is early June before it rises sufficiently to be within the range of 45-55% although once within the range the humidity only drops below the lower value slightly towards the end of December and rises above the upper value on a few occasions whilst in 2005 it drops in and out of the range throughout the year outwith summer.

Following the format of previous reports data have been divided into groups: a ‘Main Areas’ group, an ‘Extreme Areas’ group comprising the loggers that were in the problem corner of the Petrology store and ‘Archive Room’ group. Graphical illustration of the data for 2005 and 2006 are given in Figure 61 to Figure 67.

3.2.1.1 Main Sample Areas

Referring to Figure 61 & Figure 62, the year is split into two sections: the first before June 2006 and from June to December.

The first 5 months of 2006 were more even in temperature and humidity with fewer sudden large rises or falls. After the end of winter the humidity, which showed the normal seasonal cyclic lowering of humidity to March, remained low, increasing only slightly as time progressed to its maximum in late July. From there it dipped in high summer before rising again in September and dropping back in November and December. The temperature followed this, approximate, trend.

The humidity of the Museum logger only reached the lower limit briefly during October, circa 6% of the year. This is surprising as in 2005 it was within the range for almost 40% of the year. The temperature followed the trend for the other areas monitored, in fact the percentage of time the temperature achieved the desired range was slightly up on 2005, and so there is no obvious explanation for this result.

The remaining loggers follow approximately the same pattern, as expected the Palaeo store more so than the Petro.

The loggers in the Petro store vary more but still move in line with the data collected from the loggers in the Palaeo store.

This shadowing of the curves in two unconnected stores show that the changes are not man-made but influenced from outside. This is confirmed by examining the trends in the temperature in Figure 61 which can also be seen in Figure 88: Weather Murchison House, 2006.

An interesting point to note is that the internal humidity curves do not correlate as well the temperatures to the external values.

This could explained by moisture not permeating the building fabric (other than in certain places where there are specific problems) but the heat radiating into the building through the brickwork and warming the air in the stores. Consequently, this raises the air temperature in the rooms which in turn would increase the humidity. As the stores are kept closed there is little air change therefore the moist air remains in the stores.

This effect would not be altered if the store room doors were kept ajar as Murchison House is not an air conditioned building.

3.2.1.2 EXTREME AREA

A more even humidity trend was managed during 2006, although there were some dramatic increases and decreases caused by the dehumidifier switching off and on automatically.

Rather than have it varying the environment in this way it was switched off in order that the natural levels could be determined. The machine had been running almost non-stop for around two years after the corner was found to be damp due to water ingress through faulty brickwork and it was thought that perhaps over this period most of the moisture would have been removed.

The maximum level of humidity when the dehumidifier was running was within 5% or so of the upper limit of the preferred range (55%). The moisture level in the wall was also checked with a damp meter and was found to be cold but dry.

Figure 65 contains all the data from the Petrology Store. It shows the variation in the corner readings due to the dehumidifier cutting in and out. There was a concern that the humidity was being dragged down too far when the dehumidifier was running constantly. It was therefore set at a lower level which caused it to cut off when it achieved the set humidity.

In the 2006 report it was noted that we did not know how the high humidity in the corner was affecting the rest of the store as it was so extreme. However having been able to take it to a relatively low and even level before switching the dehumidifier off it was hoped any effect may be able to be detected.

As can bee seen from Figure 65 the humidity in the E Corner increased from the switch off point. It shows that the readings removed from the immediate vicinity of the corner do not show such dramatic increases but they are higher than those from the Palaeontology Store, which they had previously been shadowing relatively well. The readings are, however, still within the 45-55% range. (The dip at the start of November is due to the instruments being calibrated.)

The trend for the corner in particular and the store in general will be monitored over the coming year.

3.2.1.3 ARCHIVE ROOM

The Archive Room was created in early 2005 and monitoring commenced during June 2005; and Figure 66 and Figure 67 show the resulting curves from that time.

Although the room has a computer monitoring the temperature & humidity and controlling both to within a pre-set range it has been unable to maintain a constant temperature and humidity.

The results from the initial two loggers installed in 2005 were unexpected and therefore a third was added to check the data of these two: it was found that all loggers were reading accurately.

During the first quarter of 2006 the humidity was too low although the computer was set to a higher level. Following discussions with the installation company and attempts to improve the levels an engineer inspected the equipment and found a malfunctioning component. This was replaced and the humidity improved over the following months.

The humidity settled to a regular level that, whilst within the range of 45-55% RH, was at the higher end of that bracket. The decision to lower the computer setting to bring the humidity to the mid-point was taken and was successful.

Unfortunately whilst the humidity sits at 50% there is an unusual effect of it dropping 10% for brief periods. This was also noted at the beginning of the year but not as frequently at the higher setting.

A similar, but less dramatic, variation was noted in the temperature at the same times, although the temperature remains within the range for all but approximately 2% of the year.

The installation company has been alerted to this and the problem is being investigated, however it has been 18 months since the equipment was installed and it is disappointing that it is not working as it should.

3.2.1.4 SERVER ROOM & LIBRARY

Monitoring of the Server Room and Library only commenced in November and so there is limited data from these areas: the gaps were caused by incorrect ‘arming’ of the loggers.

There was a specific request from a member of staff to monitor the server Room as this is an area of potential high-risk to BGS business. The area is alarmed which sounds at the night-guard ‘s station if it goes outwith preset boundaries. Procedures already in place require the guard to contact the on-call member of SNS who will attempt to rectify the problem. The Library was added to bring the Edinburgh monitoring in-line with that at Keyworth, which already monitors the Library there.

Figure 68 is provided to the same scale as all other graphs although there is only a portion of the year monitored, Figure 69 can be used to examine the detail.

It can be seen that the Server Room, which is fully air conditioned has a relatively flat temperature and humidity, although for a period to Dec 30th the humidity was up to 4.5% lower than normal. There is no reason for this and will be monitored.

In the Library store, which has no air conditioning, the environment is more variable. The temperature and humidity mirror each other as the building goes through the 5-day heating cycle. The Monday to Friday temperature peeks and the gradual tail-off over the weekend before the rise on Monday morning can easily be seen.

3.2.1.5 DISCUSSION OF BAR CHART DATA

Data collected for 2005 and 2006 are presented in a series of bar charts for quick comparison.

Figure 70 & Figure 72 show the breakdown of the temperature & humidity data for 2006 in terms of that within the desired range of temperature and humidity also presented are that which are below and above the limits. Figure 71 & Figure 73 present the data for 2005.

Figure 74 displays the percentage of data within the range during 2006 alongside data for 2005 to allow direct comparison.

Figure 75 to Figure 78 expand on these charts, providing more detail, allowing direct comparison of data. Figure 75 & Figure 76 are a division of Figure 74 into single year data whilst Figure 77 & Figure 78 compare the same data but divides the "outwith range" data into above & below target, allowing us to identify where changes have occurred from 2005 to 2006.

From Figure 74 it can be seen that only two loggers recorded an increase of temperatures within range, this despite 2006 being officially one of the hottest years on record. There were also only two areas that showed an improvement in the humidity from 2005.

The slight improvement in the temperature in the Museum was offset by a sharp decrease in the Humidity within range. The only other temperature improvement was that of the SW Archive Room logger. This is in part due to the monitoring programme: we were able to identify when the temperature dropped below the required level and inform Facilities Management. However, as this area has an environmental management system in place we would expect both the temperature and humidity to be within range for a greater percentage of time than currently recorded.

Whilst the temperature for both instruments is now in the region of 95%, which is good and possibly acceptable, the humidity is only at 50%. This is obviously not acceptable and we will be working with both Facilities Management and the installation company to improve the environment in 2007.

The improvement in the RH for the North and East Corner loggers in the Petro Store is due to the running of the dehumidifier for almost 2 years taking a lot of moisture from the air in that area. It is hoped that this will be more controllable now but it will be closely monitored. The temperature in this area is very low which is of concern as we cannot alter this as there is no heating available in the store.

There was discussion in previous reports on the effect the damp corner has on other areas in the Petro store: it was thought that the damp air would circulate around the store raising the RH recorded on other loggers. If this was the case the opposite should also be true.

However, from Figure 74 we can see that whilst the humidity improves for both the Corner loggers it deteriorates for both the B1 and E831 loggers. In the detail of Figure 78 it can be seen that there is an increase in both the readings above and below the range for the B1 logger but only in the readings below the minimum. This may show that the environment is not as 'global' in the stores as first thought. This could be due to the lack of air movement around the store as there are no fans and the doors are kept closed.

The Pal. loggers show similar slight decreases in both temperature and humidity.

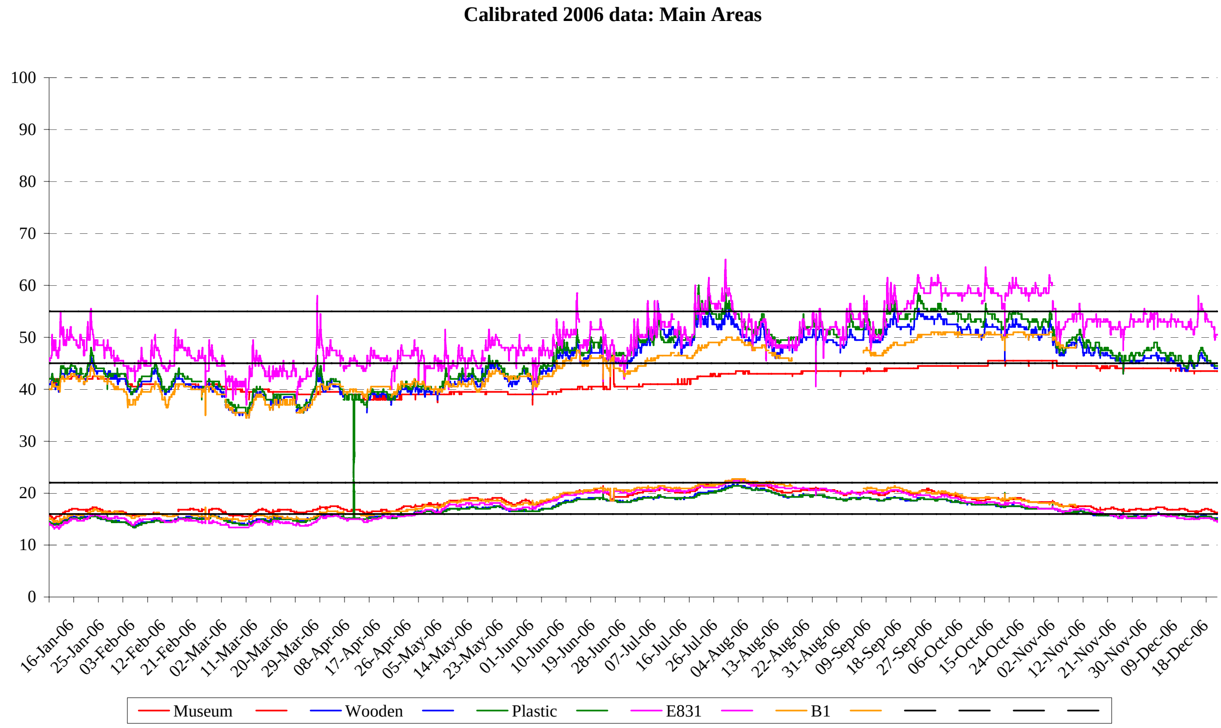

Figure 61: Calibrated data 2006: Main Areas, Murchison House

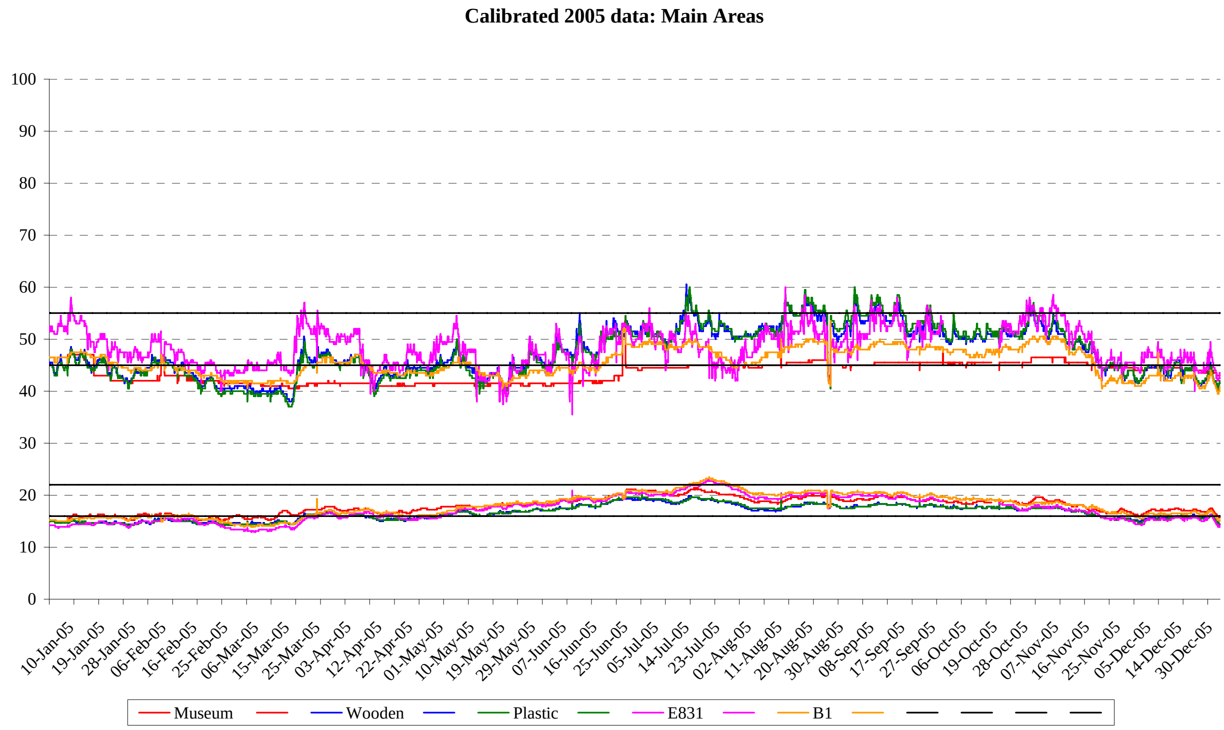

Figure 62 Calibrated data 2005: Main Areas, Murchison House

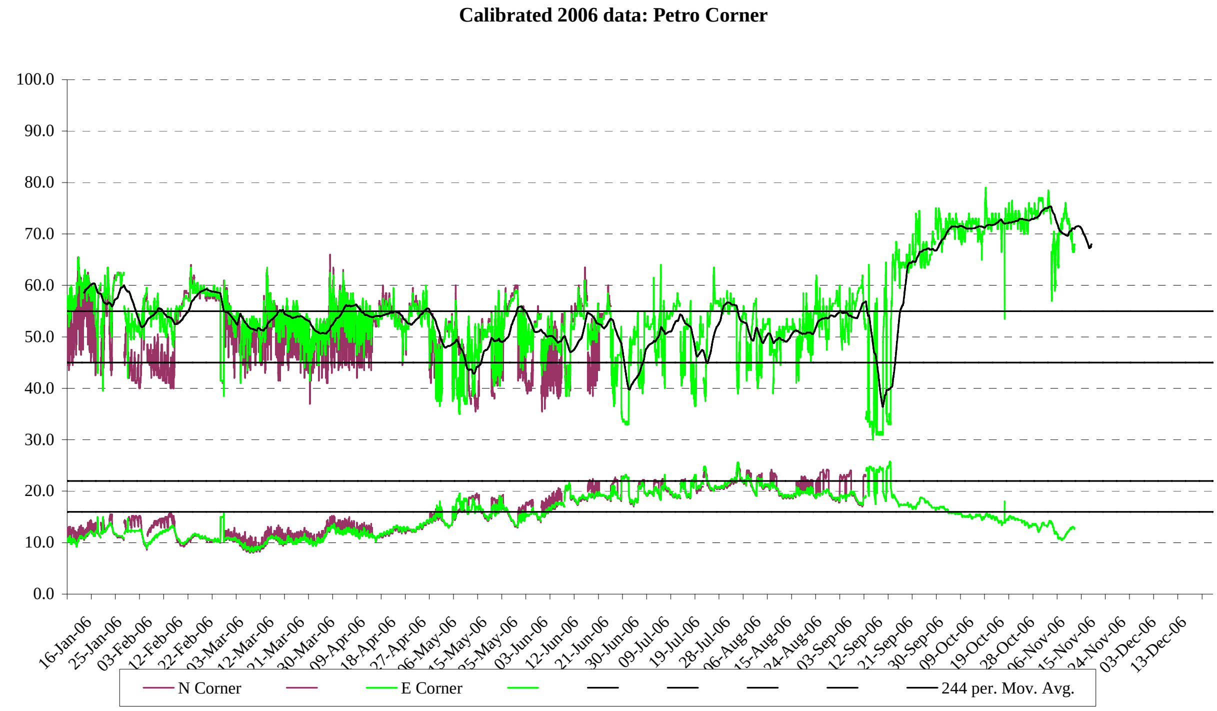

Figure 63 Calibrated data 2006: Extreme Area, Murchison House

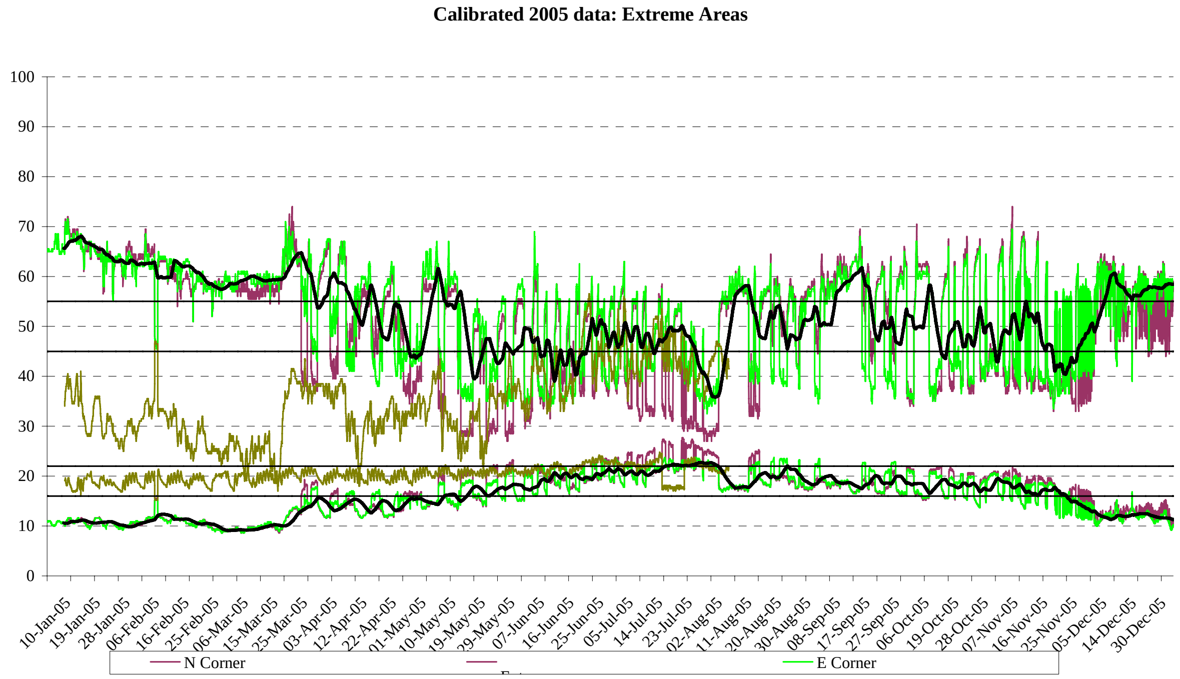

Figure 64 Calibrated data 2005: Extreme Area, Murchison House

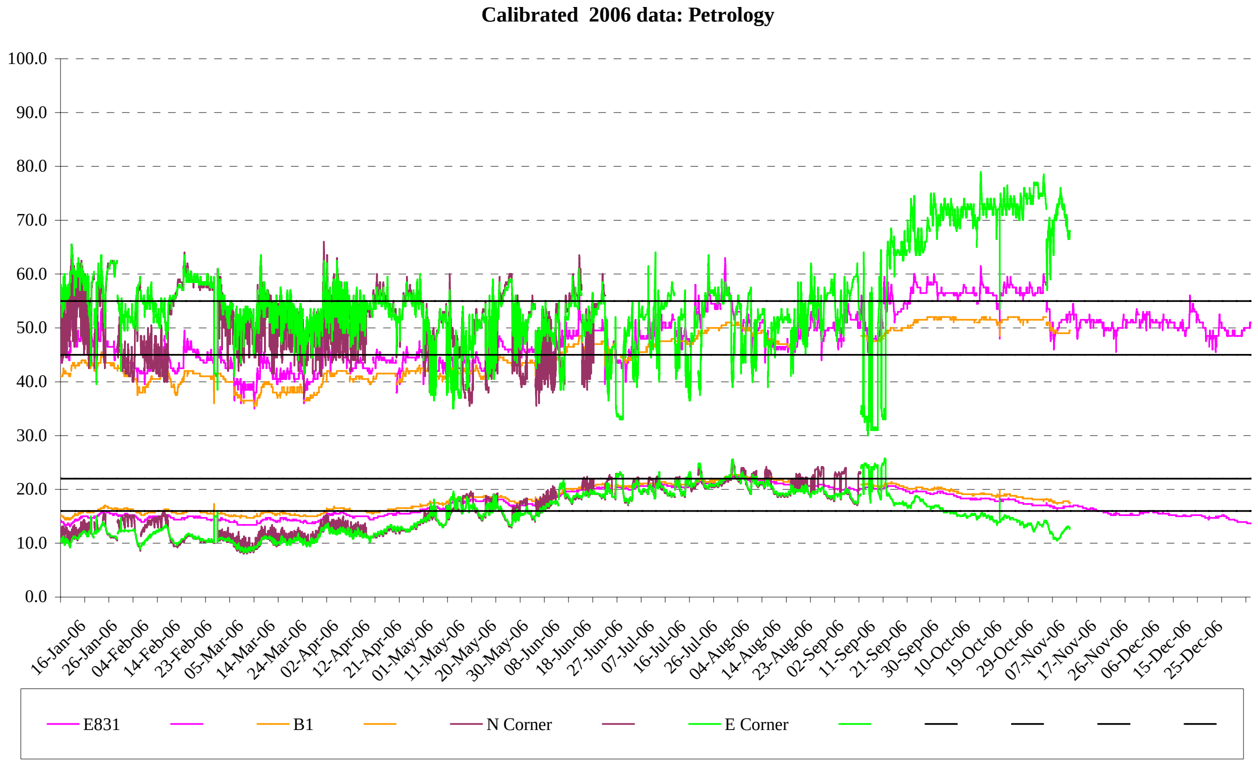

Figure 65 Calibrated data 2006: Petrology Store, Murchison House

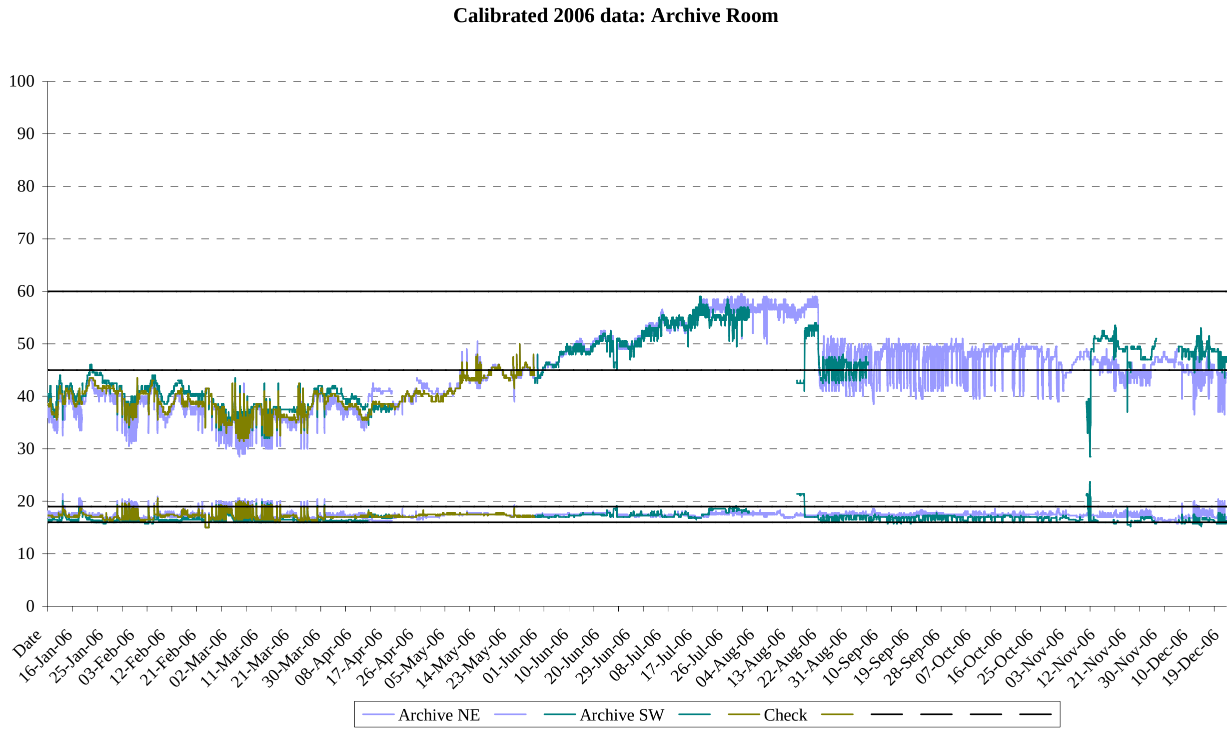

Figure 66 Calibrated data 2006: Archive Room, Murchison House

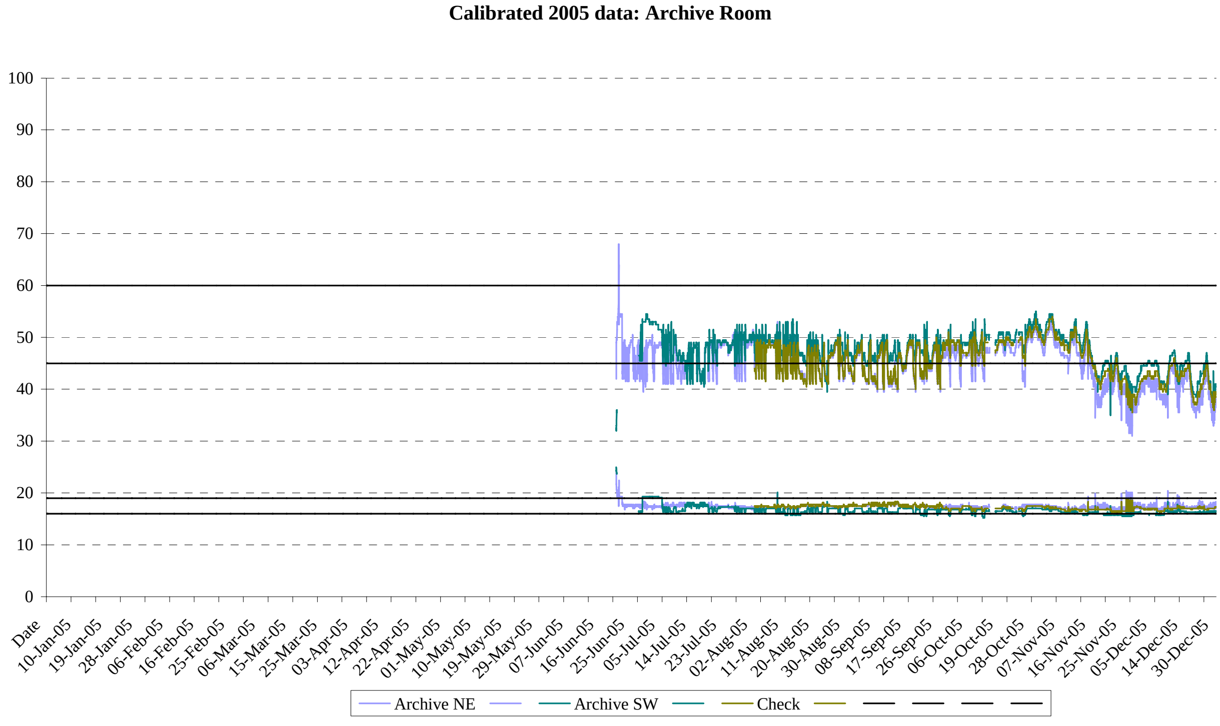

Figure 67 Calibrated data 2005: Archive Room, Murchison House

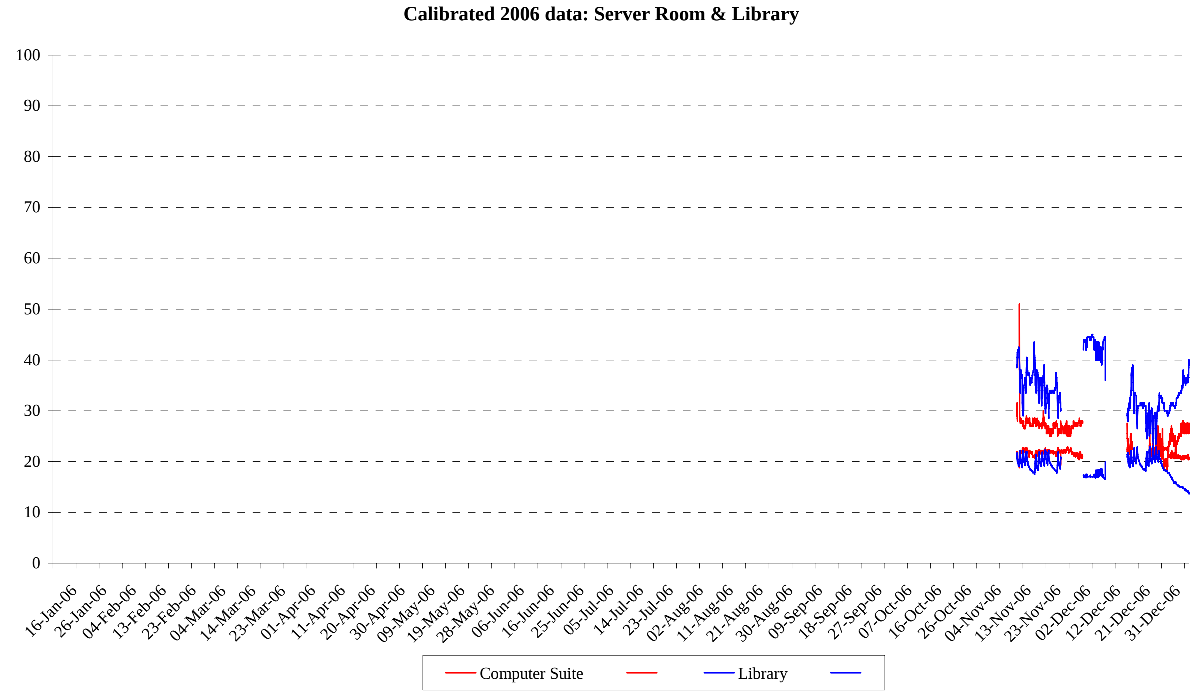

Figure 68 Calibrated data 2006: Server Room & Library, Murchison House

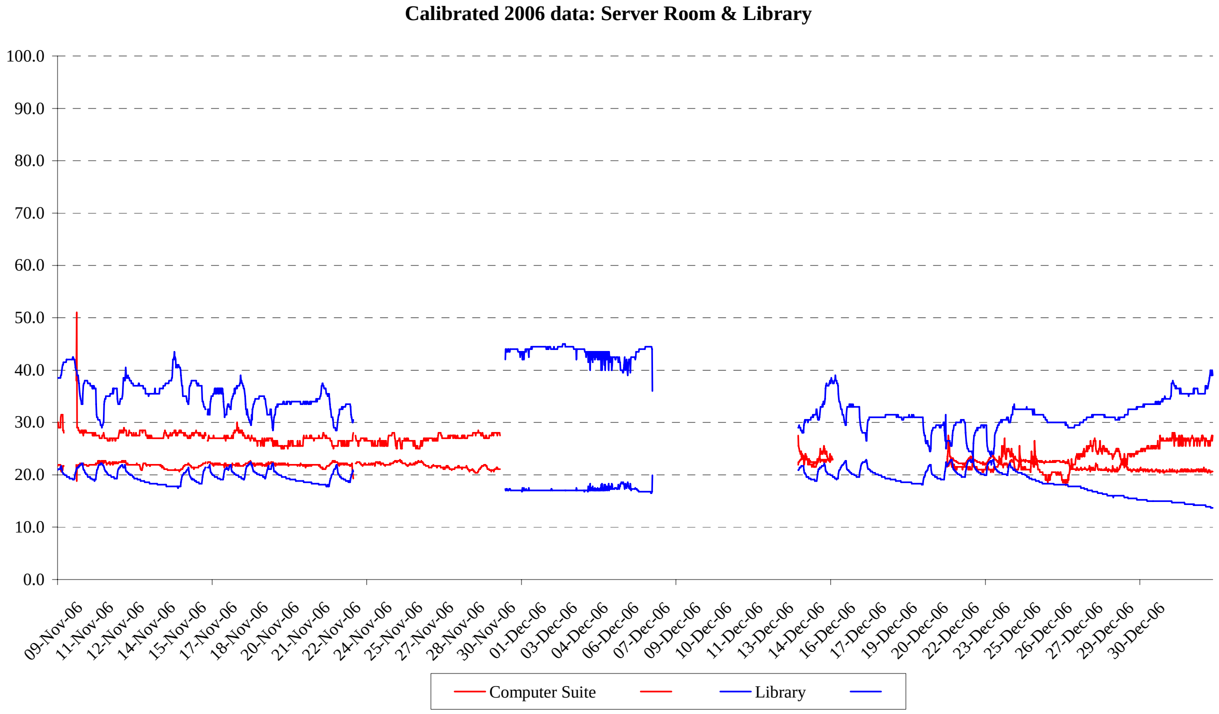

Figure 69 Calibrated data 2006: Server Room & Library (detail), Murchison House

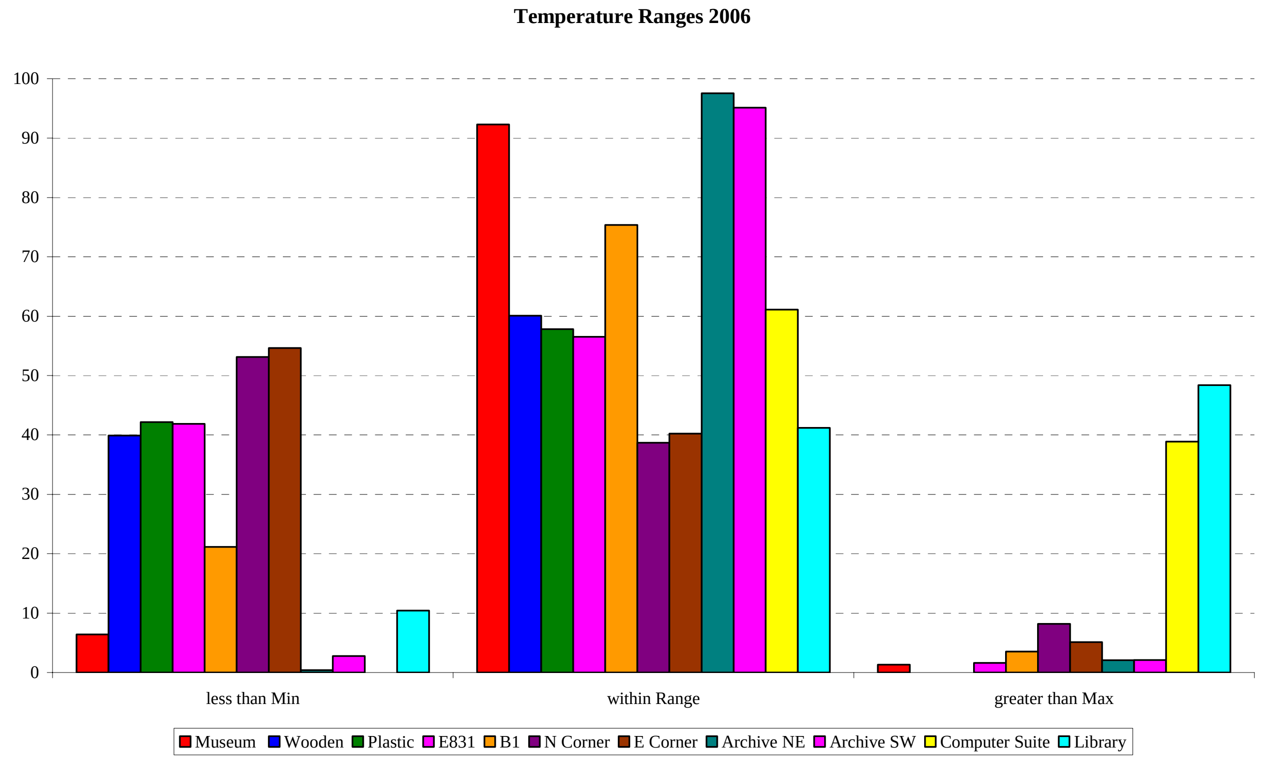

Figure 70 Temperature Ranges 2006

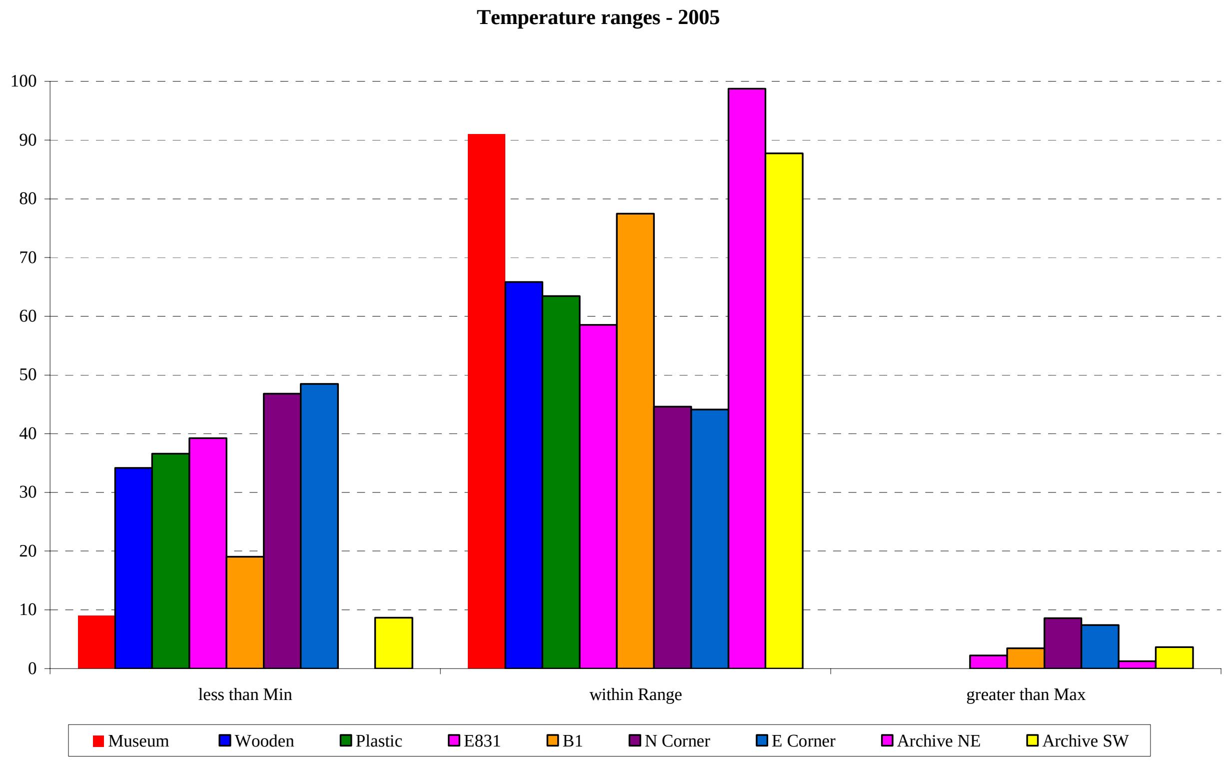

Figure 71 Temperature Ranges 2005 response

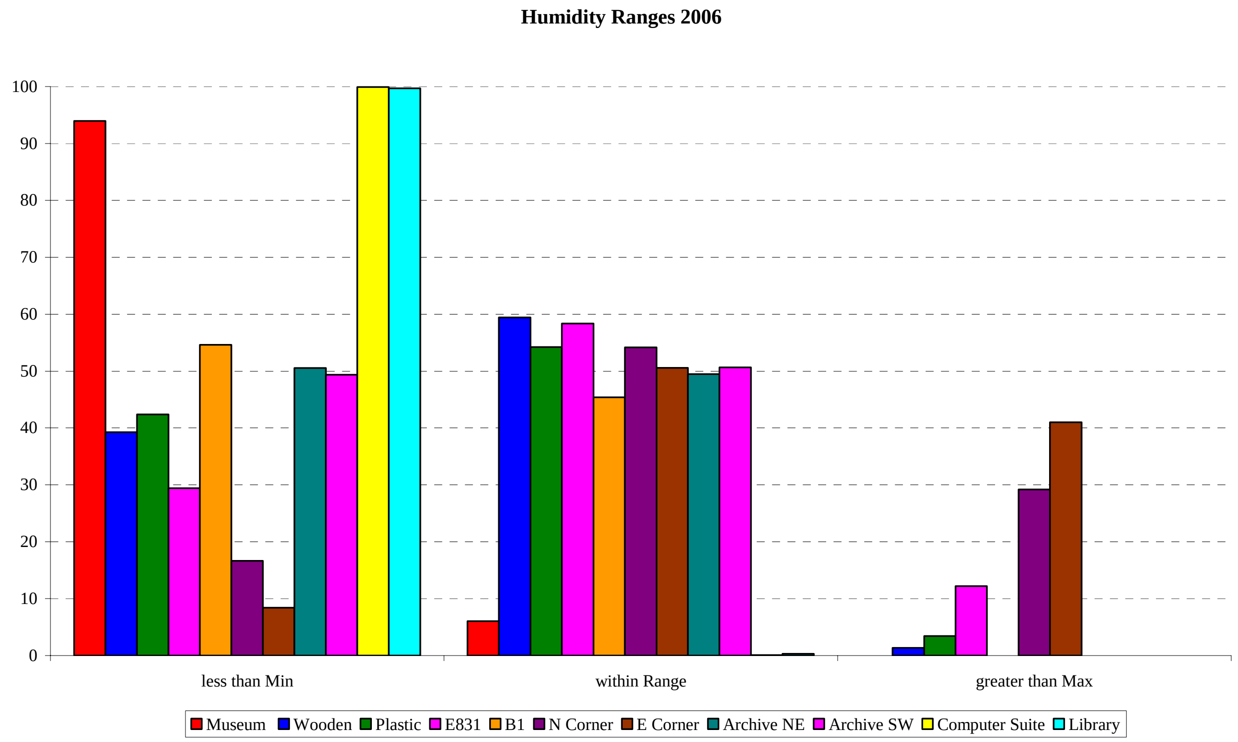

Figure 72 Humidity Ranges 2006

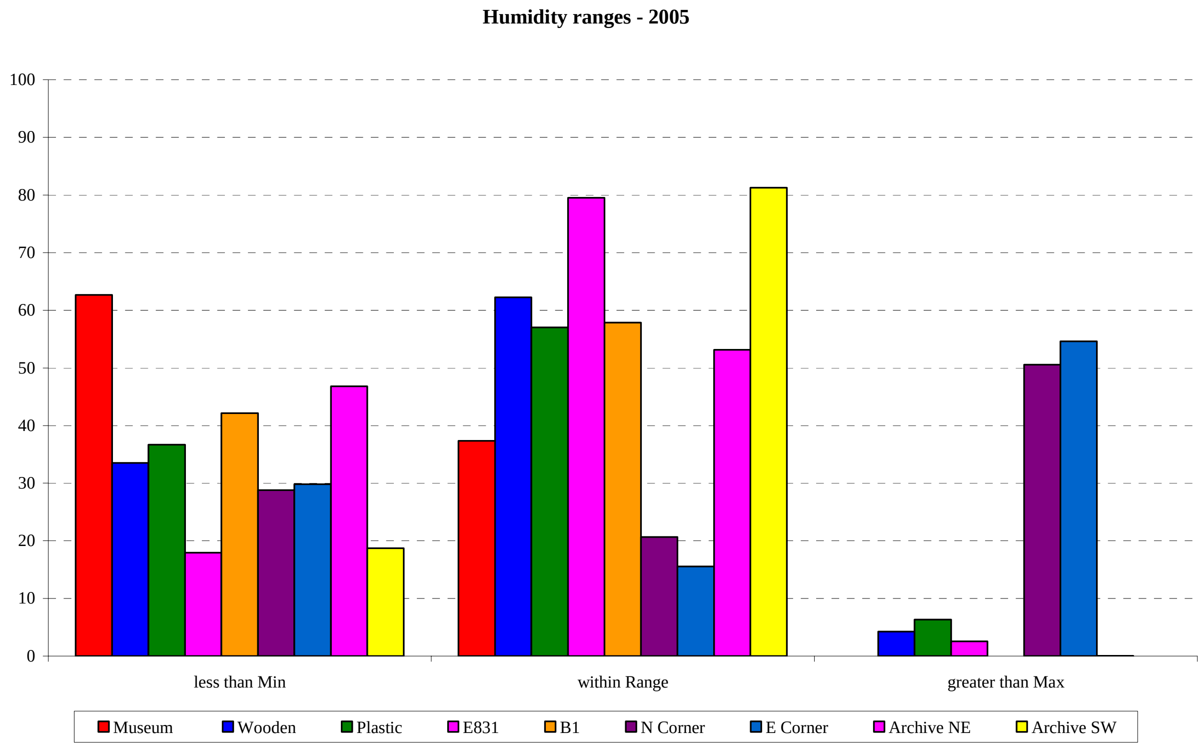

Figure 73 Humidity Ranges 2005

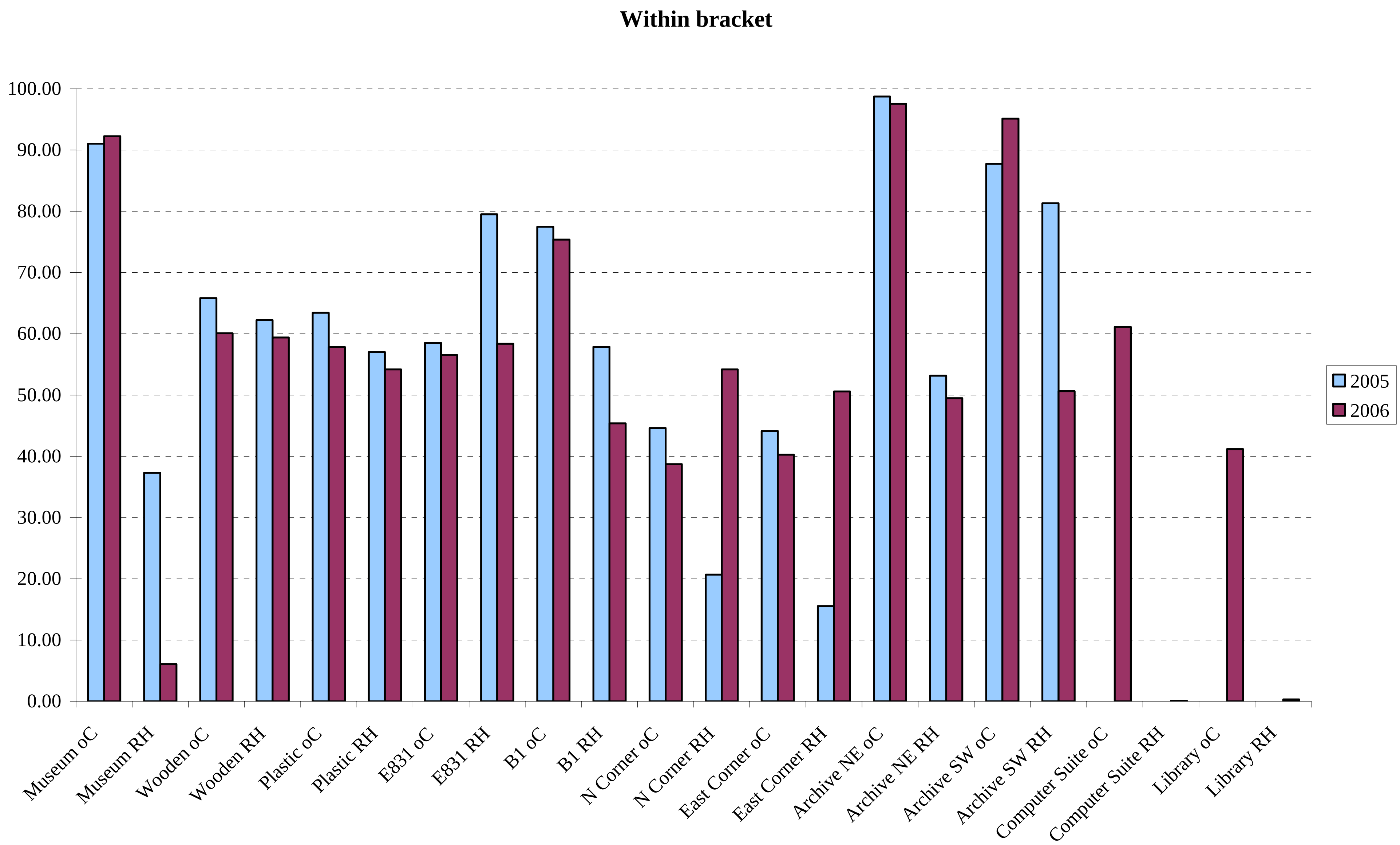

Figure 74: 2005/2006 Temperature/Humidity target success comparison, Murchison House

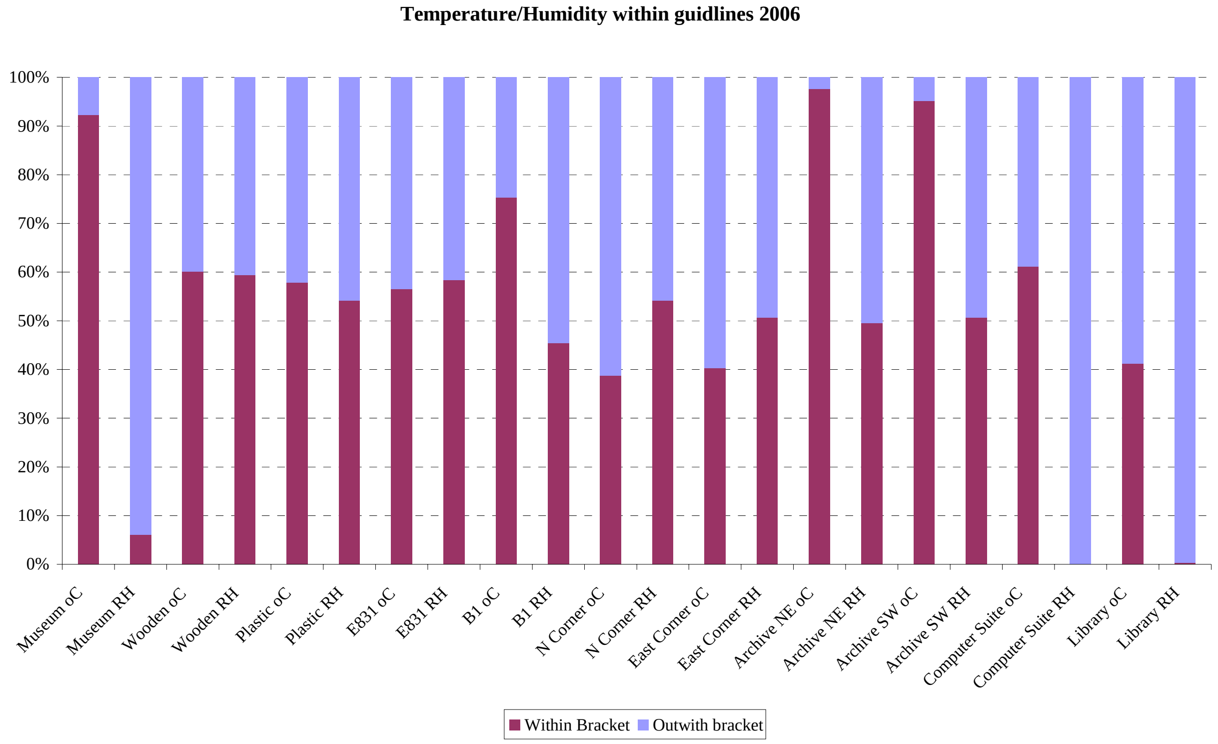

Figure 75: 2006 Temperature/Humidity target success breakdown, Murchison House

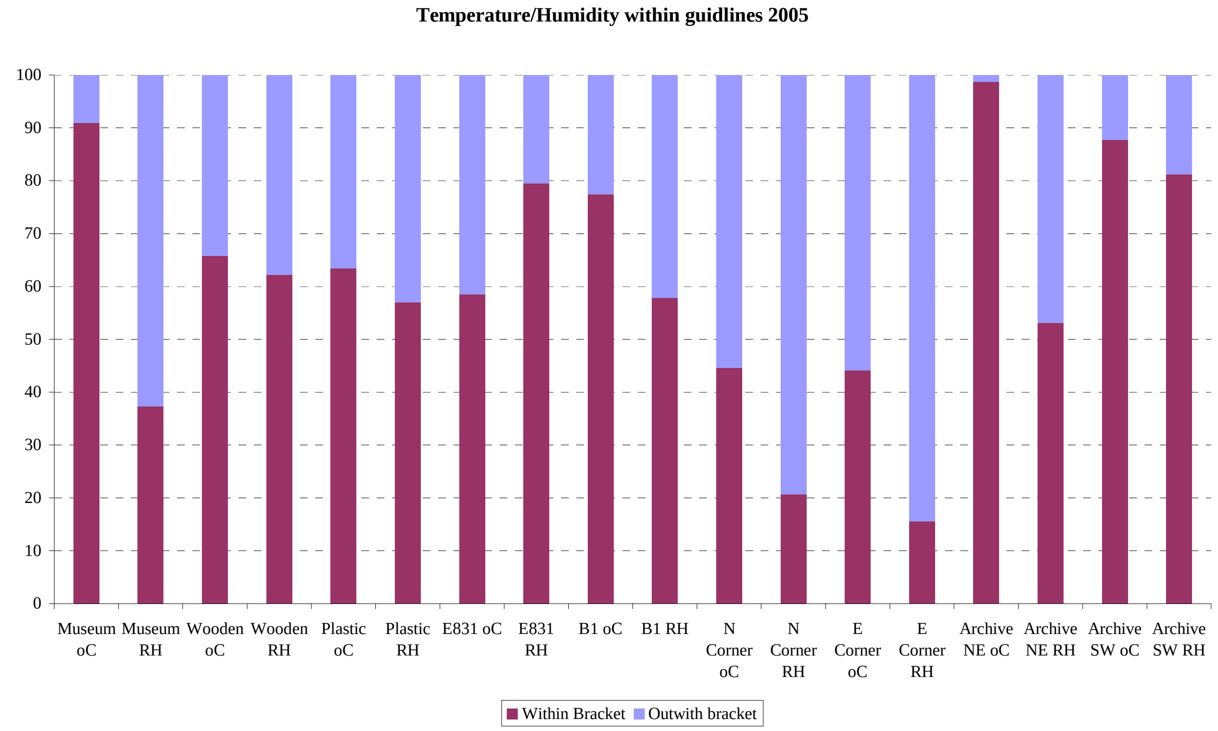

Figure 76: 2005 Temperature/Humidity target success breakdown, Murchison House

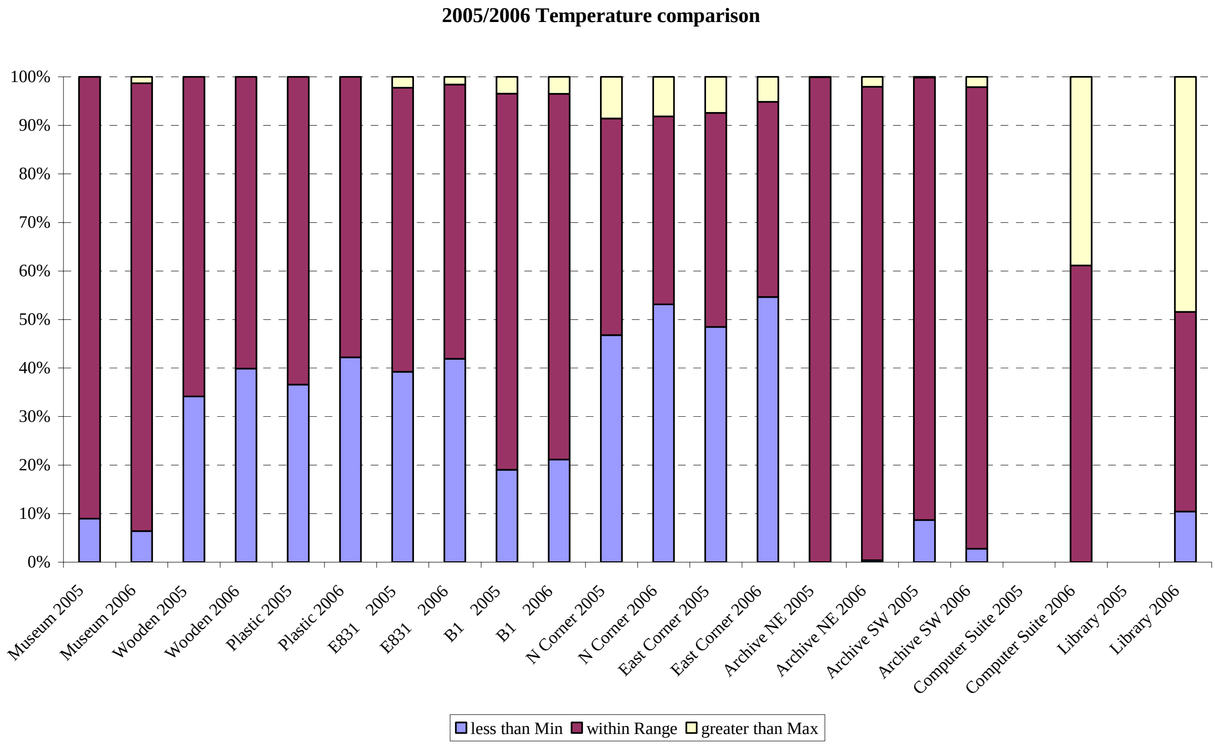

Figure 77: 2005/2006 Temperature comparisons, Murchison House

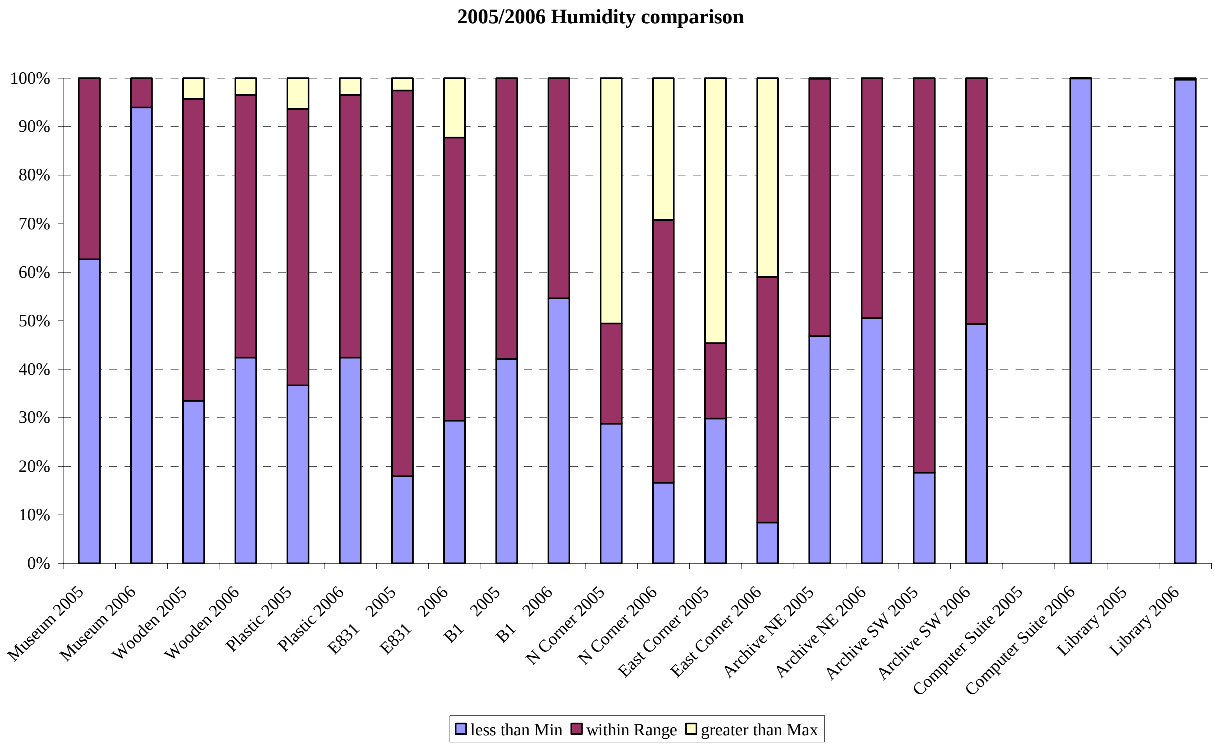

Figure 78: 2005/2006 Humidity comparisons, Murchison House

3.3 MONITORING AT LOANHEAD

3.3.1 Loanhead Core Store

One of the suggestions to come from TNA (The National Archive) Audit in Edinburgh in September 2005 was that both the Loanhead & Gilmerton core stores should be monitored. Four loggers were purchased for each site and monitoring commenced in April 2006 following a false start after the first batch of loggers were returned to be recalibrated and a period of checking in Murchison House. An additional two have been installed in offices at Loanhead following comments from colleagues on the excessive temperatures during the summer.

In the interests of inter-discipline relations these two loggers are downloaded by Collections staff as part of the monthly programme and results presented to Facilities Management.

The Loanhead Core Store is 5 miles south of Murchison House; it is a large warehouse design building approx 75m x 30m, 6.8m to the eaves, consisting of single skinned metal cladding sitting on a 1.5m high brick wall. The roof is asbestos composite corrugated sheeting with a number of plastic roof lights.

The building is currently a multi-use facility housing the Marine Sample Collection, Land Survey Borehole Collection and the Library, Bookshop & Cartography stores. It also houses a portion of the magnetic tape collection and equipment from the Seismology & Geomagnetism programme.

Staff managing these archives do not have a permanent presence on site, rather they visit as required. However, there are 9 full-time staff based at Loanhead from the Marine, Coastal & Hydrocarbons programme, Marine Operations and Engineering section, the majority of these are either electrical or mechanical engineers developing and maintaining offshore sampling equipment.

The size and fabric of the building means that it is uneconomic to heat in the winter or cool in the summer. Although large gas fan-heaters and electric de-stratification fans were installed several years ago these have had minimal effect on the environment due to the construction of the building and the activities within it. There have also been roof leaks although these have largely been repaired.

There are other issues that make it difficult to manage the environment in a facility shared, not least that the door is often left open compensate for the low-level of natural daylight obtained from the poor roof-lights and to allow frequent access to the yard by engineers, making environmental control impossible.

The loggers have been placed in a column at approximately 0.75m, 1.9m, 2.6m and 4m in the centre of the shelving. They will be kept in this location for 12 months when three of the loggers will be moved to another location. The logger retained in the original position will allow comparisons to be made with the new location.

3.3.2 Annual Data Discussion

From earlier readings in 1998 and 1999 when the environment was monitored for two months in each year it is known that the core store is not “fit for purpose”. Figure 80 displays the readings obtained during July and August 1998 where it can be seen that at only one point does the humidity fall within the range and this for only a 6 hour period in mid-July. The temperature performs slightly better although it sits on the lower end of the scale and continually dips in and out of the range, fluctuating between 13^{o}C and 20.6^{o}C.

Figure 79 is a graph of the same period in 2006; it shows that whilst both the temperature and humidity still fluctuate, unsurprisingly on a daily cycle, they are within the range for longer.

Whilst the humidity is still high the same can be said this: it merely dips into range although in 2006 on a number of occasions.

The logger locations can be directly correlated to the readings. Logger 1 is the lowest and logger 4 the highest, the readings reflect the difference in height: as expected the higher loggers show higher temperatures and lower humidity levels.

Since the earlier monitoring there has been a change in activities in the store: the engineering department has seen an expansion of personnel and an increase in fabrication and maintenance of equipment.

It should also be pointed out that 2006 was the warmest year on record. Although the weather will be discussed in a later chapter Figure 81 has been provided to allow comparison of the internal and external readings.

Bearing in mind the distance between the stores the figures should not be expected to be directly comparable at all times however the temperatures fluctuate in a similar manner even though those of the store are slightly higher. Although the building fabric possesses few insulating properties it is sufficient to offer some shelter from the wind and retain some daytime heat, the contents of the building also provide a form of heat storage. I suggest these factors account for the perceived improvement during the 2006 period.

Monitoring of the store in 2006 commenced on 21 April and has been continuous other than at periods when the instruments were not recording due to the buffer being full or failure to rearm correctly.

Comparing Figure 82 and Figure 83 it can be seen that the conditions inside the store reflect those outside, albeit slightly damped. The temperature highs and lows throughout the period monitored can be mapped across the two graphs. The Loanhead graph shows that the store is rarely within the 16-22^{o}C temperature range or 45-55% RH range.

The trends in the humidity curves do not match as closely as the temperature, however they are similar: the readings from inside the store generally reflect the external trends.

3.4 MONITORING AT GILMERTON

3.4.1 Gilmerton Core Store

As discussed above environmental monitoring commenced in April 2006 following a TNA Audit in Edinburgh in September 2005.

The Gilmerton Core Store is 3 miles southeast of Murchison House, it is a large building (8500m^2 and approx, 6.8m to the eaves) of warehouse design, consisting of insulated metal cladding sitting on a 1.5m high brick wall. The roof is insulated corrugated metal sheeting with a high number of large roof lights.

The main storage building is single-use housing the offshore hydrocarbon exploration sample archive from the UK Continental Shelf.

There are 4 full-time Collections staff and a number of others working on another project based at Gilmerton.

As with Loanhead the fabric and size of the building means that it is uneconomic to heat in the winter or cool in the summer. However as the building is partially insulated the extremes of the weather are damped to a greater extent than at Loanhead.

The loggers have been placed in a column at approximately 0.75m, 1.9m, 2.6m and 4m height at the end of a row of shelving in an open area that benefits from indirect sunshine. As with Loanhead, they will be kept in this location for 12 months when three of the loggers will be moved to another location. The logger retained in the original position will allow comparisons to be made with the new location.

The building is split naturally into 3 areas; one of approximately 1024m^2, is separated from the others by a door which is kept closed at all times other than when used for access/egress. The remaining two areas, of approximately 2300m^2 and 1536m^2, are open to each other by means of two doorways; one to allow forklift movement, the other a pedestrian route.

3.4.2 Annual Data Discussion

The management of the building and sample collection have only recently been transferred to the keeping of the BGS and as a result we have no record of past environmental conditions with which to compare the 2006 readings. Continuous monitoring of the store commenced on 21 April 2006.

As with Loanhead we can compare the weather readings taken at Murchison House, Figure 84 and Figure 85, although as with the Loanhead data it must be remembered that this store is remote form the weather station.

It can be seen is that the temperatures fluctuation within the store is similar to the outside although those of the store are consistently higher and up to 6^{o}C higher than the comparable time at Loanhead.

The Gilmerton building is partially insulated which allows it to retain some daytime heat; the contents of the building, shelving, sample boxes etc., also provide a form of heat storage to the building. These factors are reflected in the raised average temperature and the reduced fluctuations identified.

It can be seen that the conditions inside the store reflect those outside, albeit slightly damped. The temperature highs and lows throughout the period monitored can be mapped across the two graphs. The Gilmerton graph shows that the store is frequently within the 16-22^{o}C temperature range or 45-55% RH range, the temperature at times is too high. As with Loanhead the humidity is not as constant or ideal.

The trends in the humidity curves do not match as closely as the temperature although the Gilmerton curve is similar to that of the Loanhead data. Note the sudden rise in humidity at the beginning of July and the drop at the beginning of November on both Figure 82 and Figure 84: the uninsulated, more open building shows the greatest changes but both stores show the same changes. These variations can also be detected less dramatically in Figure 61: Calibrated data 2006: Main Areas, Murchison House.

Generally it is not surprising, given that it is insulated, the Gilmerton store is a better environment for the samples held there, although it is not ideal as both the temperature and humidity fluctuate significantly.

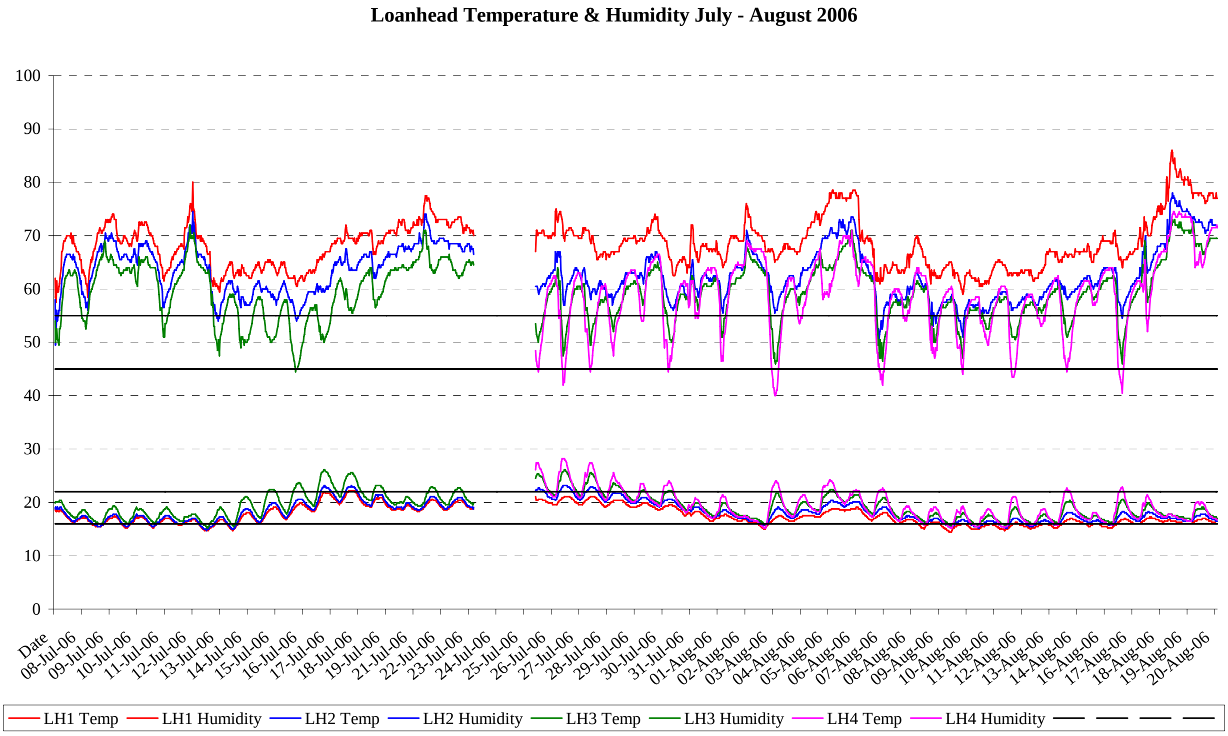

Figure 79: Calibrated data July - August 2006: Loanhead

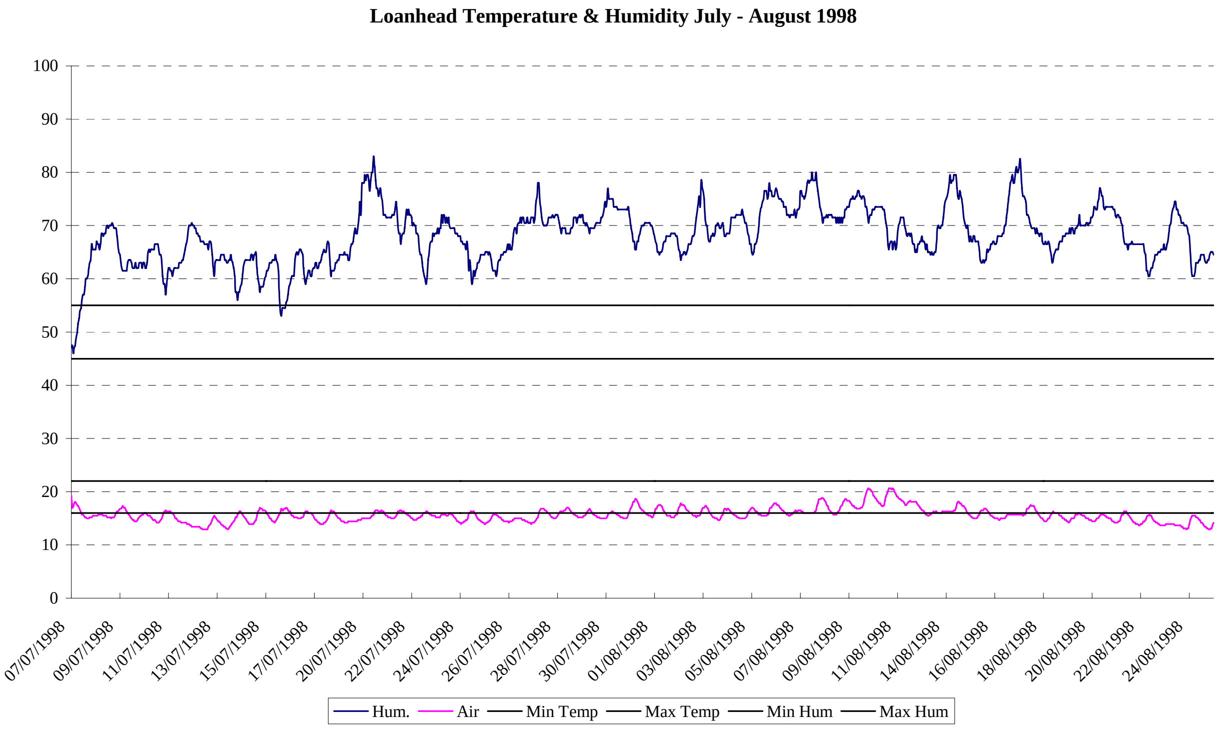

Figure 80: Calibrated data July - August 1998: Loanhead

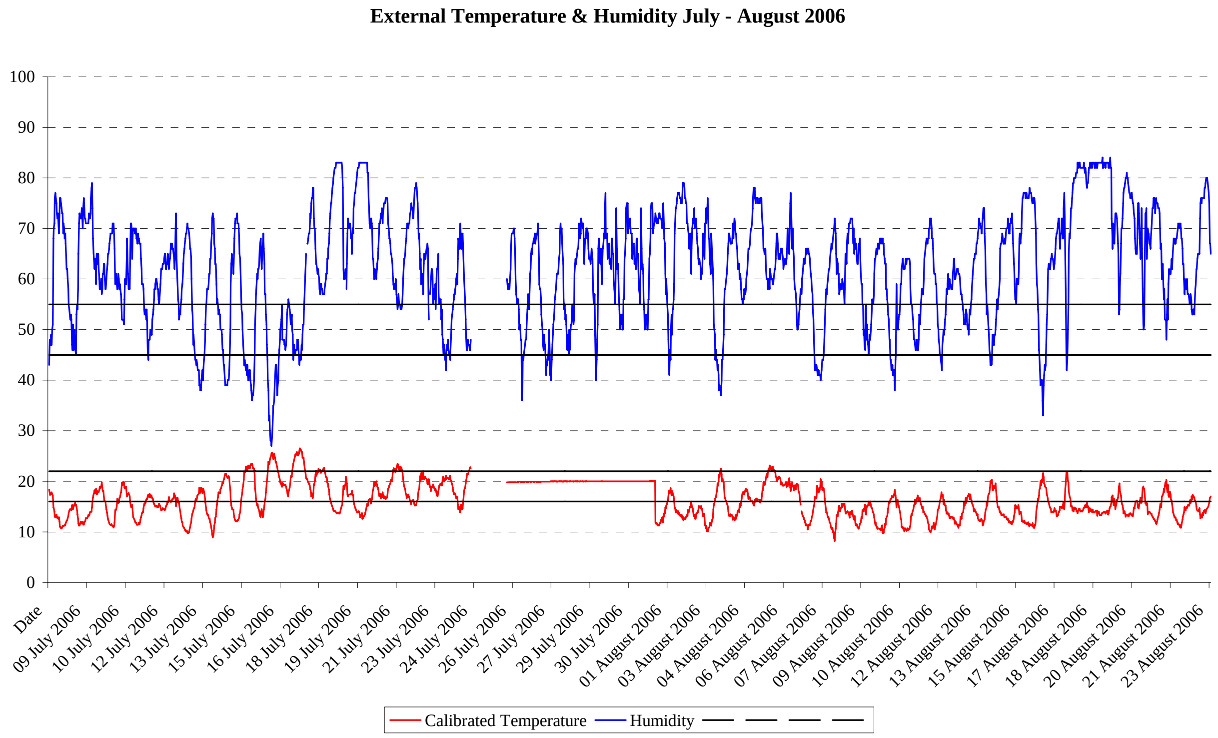

Figure 81: External temperature & Humidity July - August 2006: Murchison House

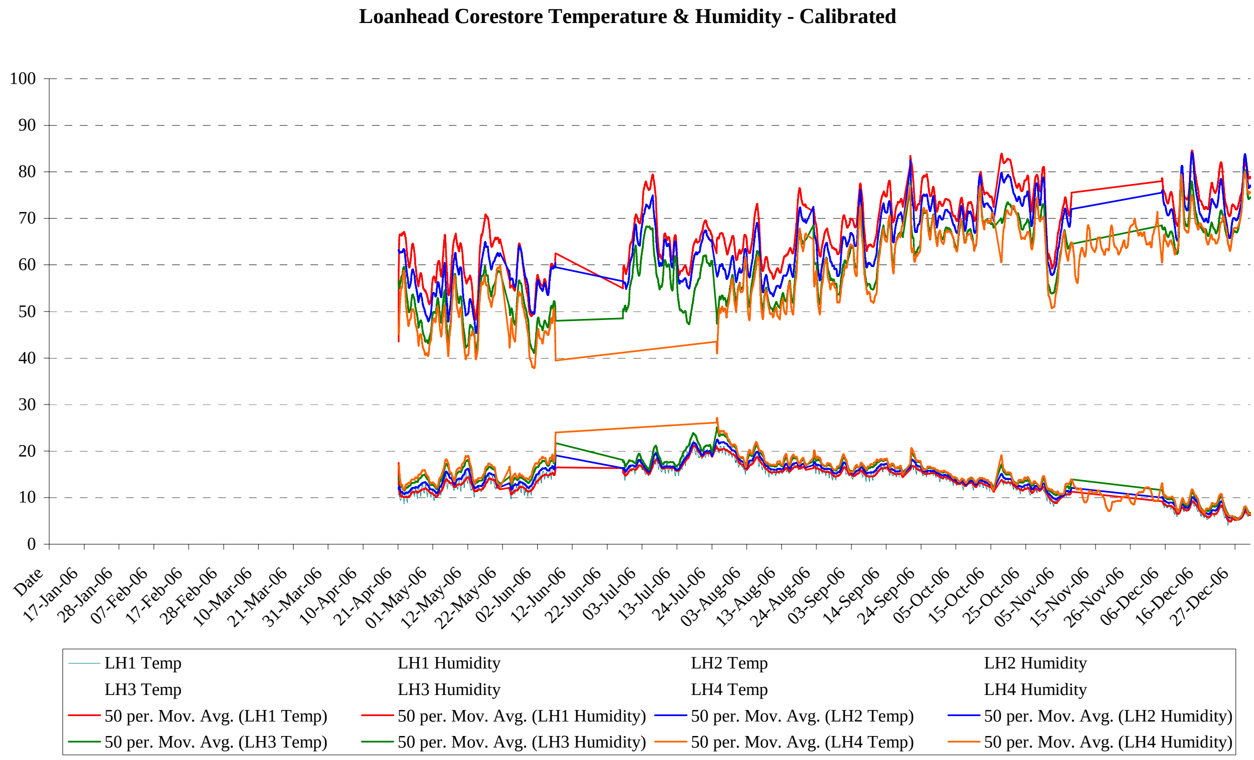

Figure 82: Calibrated data 2006: Loanhead

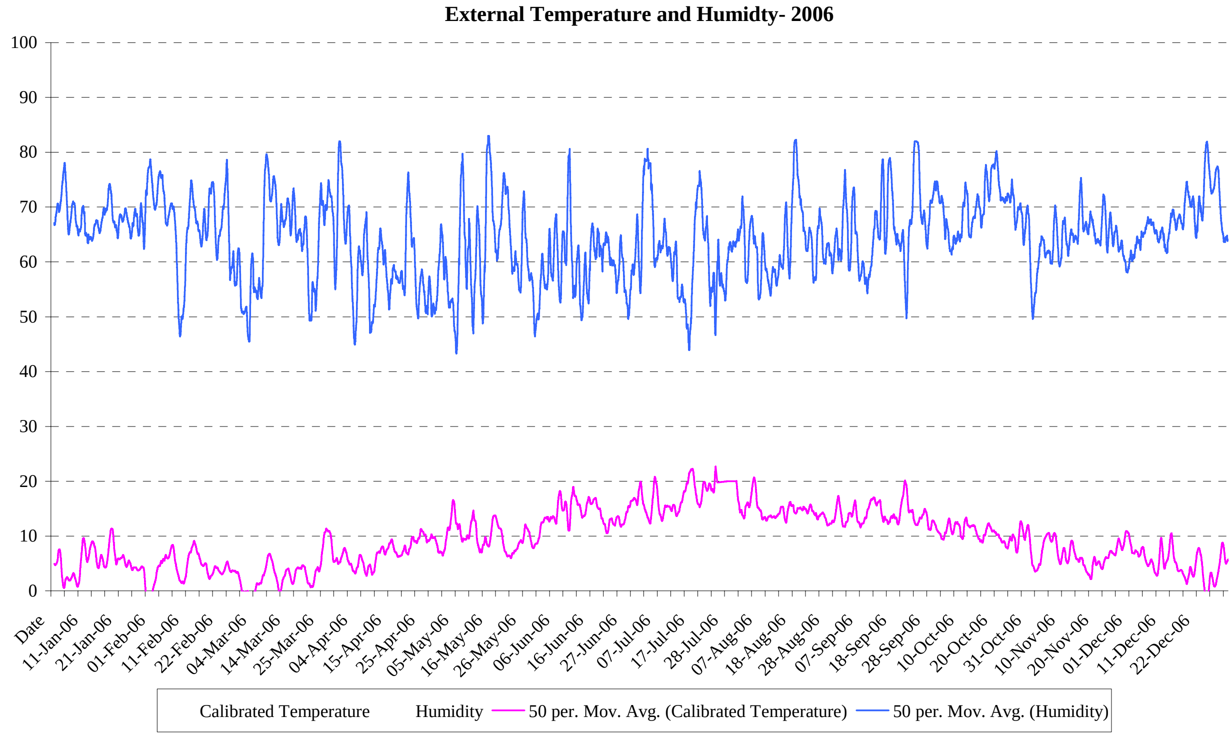

Figure 83: External Temperature & Humidity 2006: Murchison House

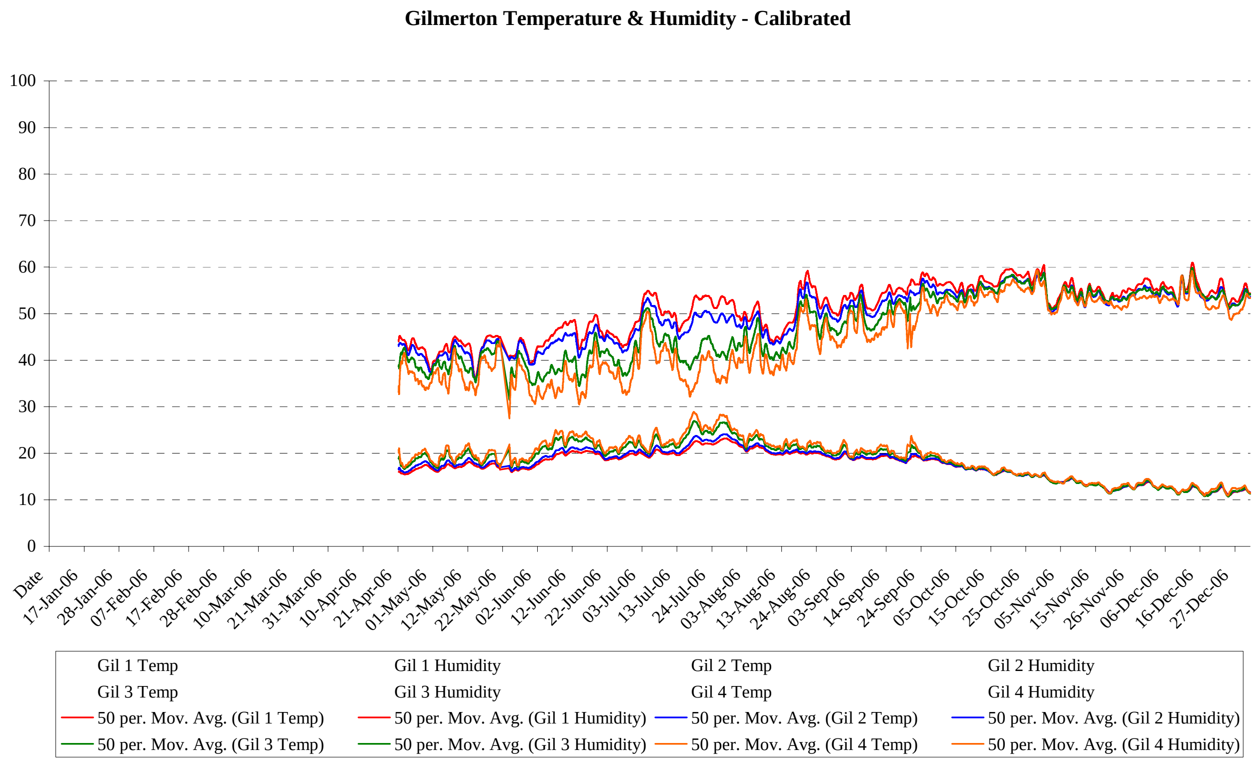

Figure 84: Calibrated data 2006: Gilmerton

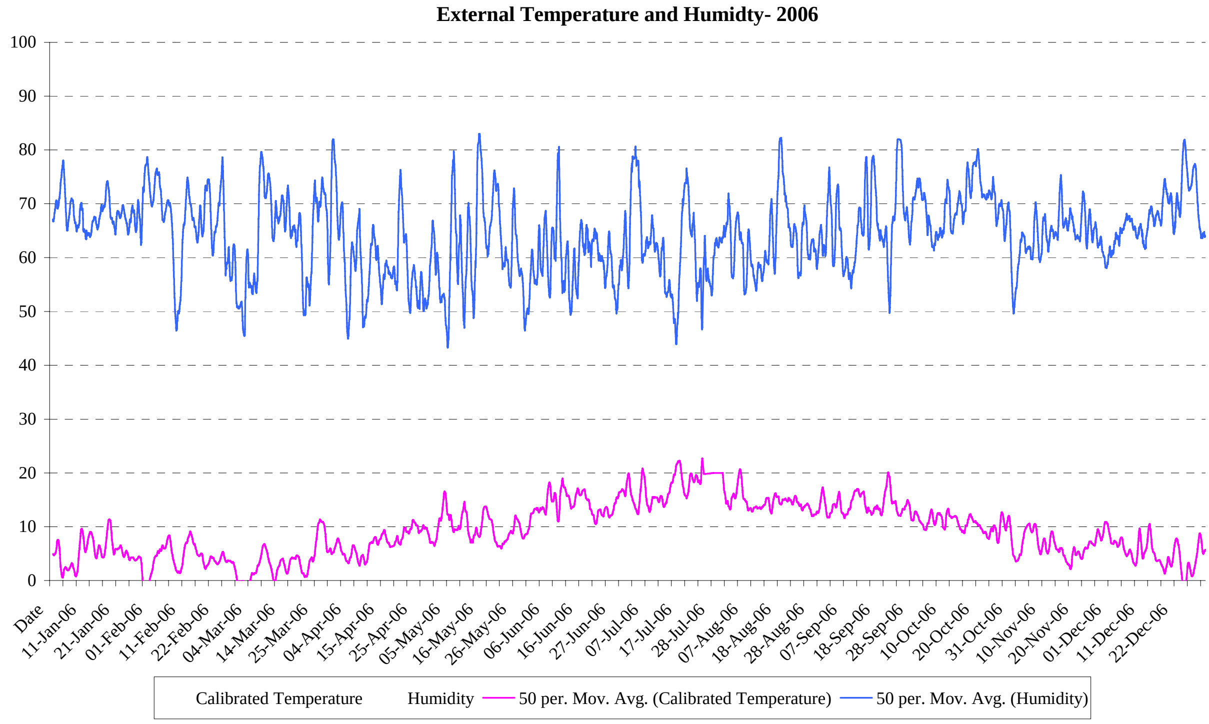

Figure 85: External Temperature & Humidity 2006: Murchison House

3.5 ANNUAL WEATHER DATA 2006

External data at Murchison House are recorded from a BGS built weather station situated on the roof of Murchison House. Data are recorded on a desktop computer and automatically stored in files in one-second intervals, extracted as 1-minute data in 24-hour files.

The recording of this data will provide in future years data against which we can plot changes in the environment of the various stores to enhance comparative discussion.

Data from May to November 2005 was used by Renewable Devices Energy Solutions Ltd. in early 2006 to compile their report *Wind Energy Preliminary Assessment and Economic Feasibility Study* to determine if the installation of a small wind turbine on Murchison House was economically viable.

The weather station was calibrated against an internal logger in February 2006. Due to the variability of the external conditions compared to those in the store rooms it is difficult to obtain an accurate calibration factor for this unit, however the 'best fit' graph is shown in Figure 86 below.

As reported in 2006, to improve the data recording of the weather station the management of the equipment was taken over by Collections, although the servicing has remained with Seismology and Geomagnetism. This has proven to be a worthwhile exercise as the computer used to record the data in the first half of 2006 remained unreliable but the periods of downtime were reduced substantially by monitoring via a desktop interface.

The continued and increasing number of drop-outs experienced necessitated a replacement, the opportunity to re-site the computer was taken and the cabling was re-routed making it easier to interrogate in the event of future problems.

This was carried out with the assistance of engineers from the Seismology & Geomagnetism Programme. Unfortunately a combination of staff unavailability and technical problems, it was not recognised that the data, although displaying correctly was not being recorded properly, there is therefore a gap in some the data during July & August.

However a more complete set of data for the calendar year was achieved than previously and it is hoped that a complete set will now be available as the new setup appears to be very stable.

For clearer examination of the weather data two trend lines have been included in the graphs. One at a 50-point moving average removes the clutter in the graph of the changing maximum & minimum readings and another of 232-point moving average allowing the annual trend to be identified.

By including the rainfall figure (multiplied by a factor of ten for clarity) we have most of the external factors that influence the environment in the various stores on one graph for each year, Figure 88 for 2006 and Figure 89 2005. Monthly totals are given in Figure 87: it should be remembered that ther is data missing due to the technical problems discussed above.

The rapid fluctuations in the humidity discussed in the previous chapter can be noted in Figure 88. In July the rise occurs at a point where there is an increase in temperature and a period of rain. Conversely the November drop is when the temperature is on a downward trend and a period of very high rainfall.

Comparing Figure 88 and Figure 89 it is noticeable that the rainfall is higher in 2006: the peaks indicating rainfall in 30-minute intervals are larger and the frequency closer together.

The 2006 Wind Speed and Direction data is presented as a rose diagram in Figure 90 with that of 2005 in Figure 91. One can see that the general wind direction over the 12 months of 2006 is very similar to that for the recorded period in 2005 and that there are more red bands in 2006 and that they are also thicker, indicating stronger the winds experienced.

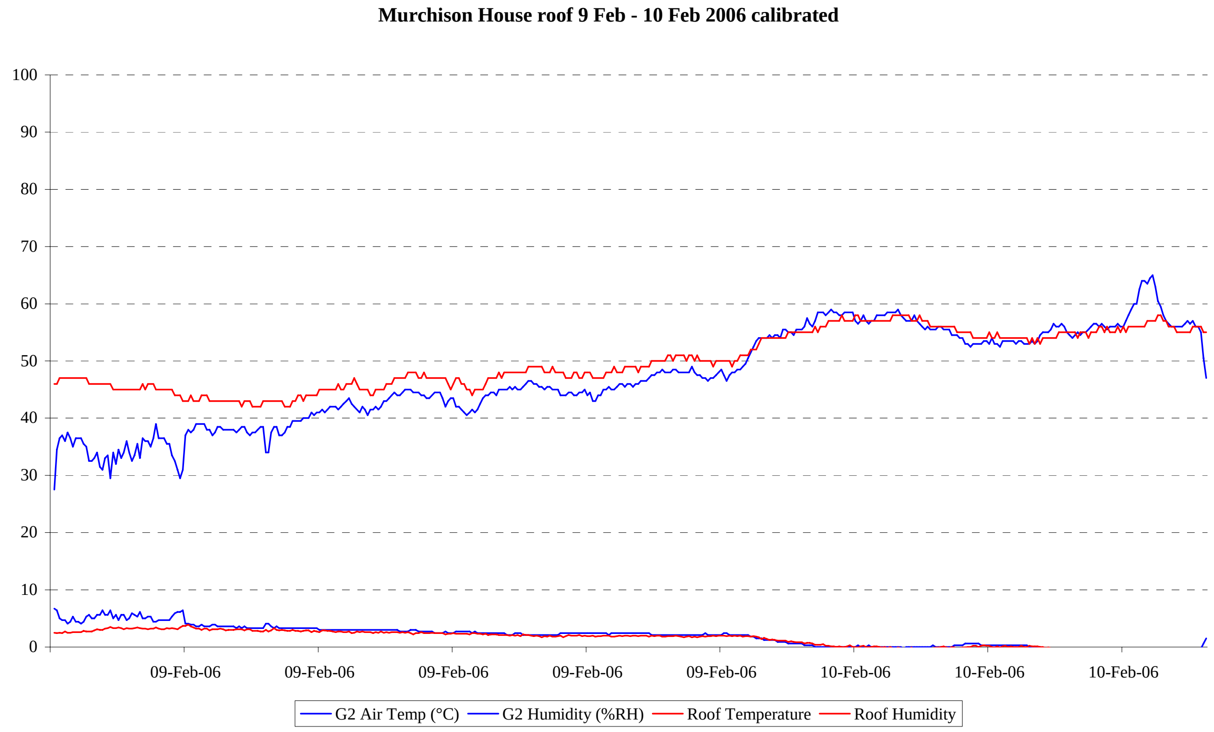

Figure 86: Calibrated data, Weather Station Murchison House, Feb 2006

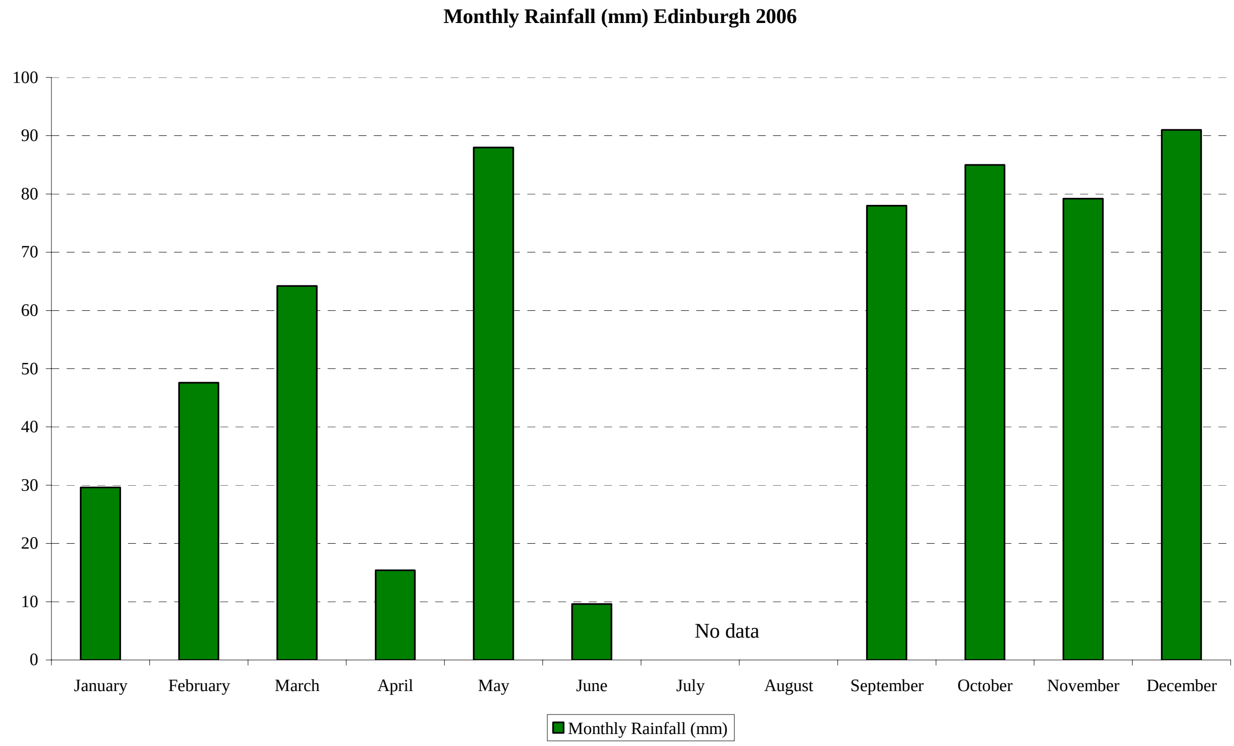

Figure 87: Monthly Rainfall: Murchison House, 2006

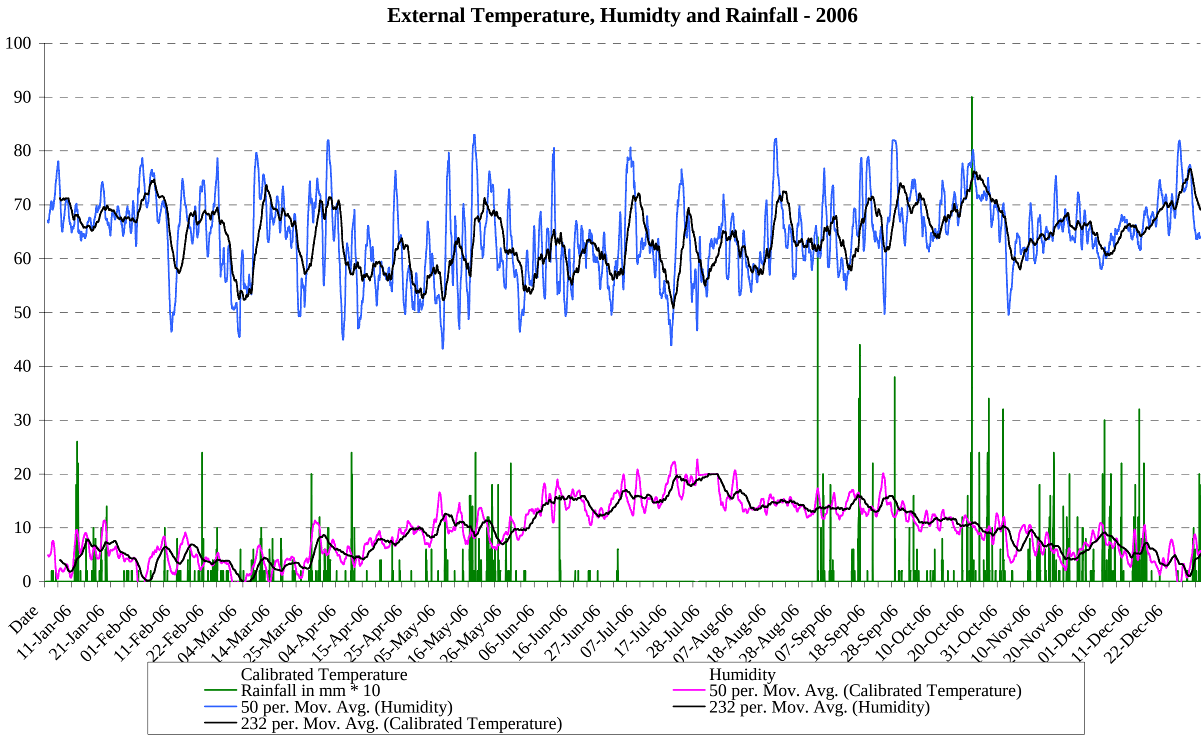

Figure 88: Weather Murchison House, 2006

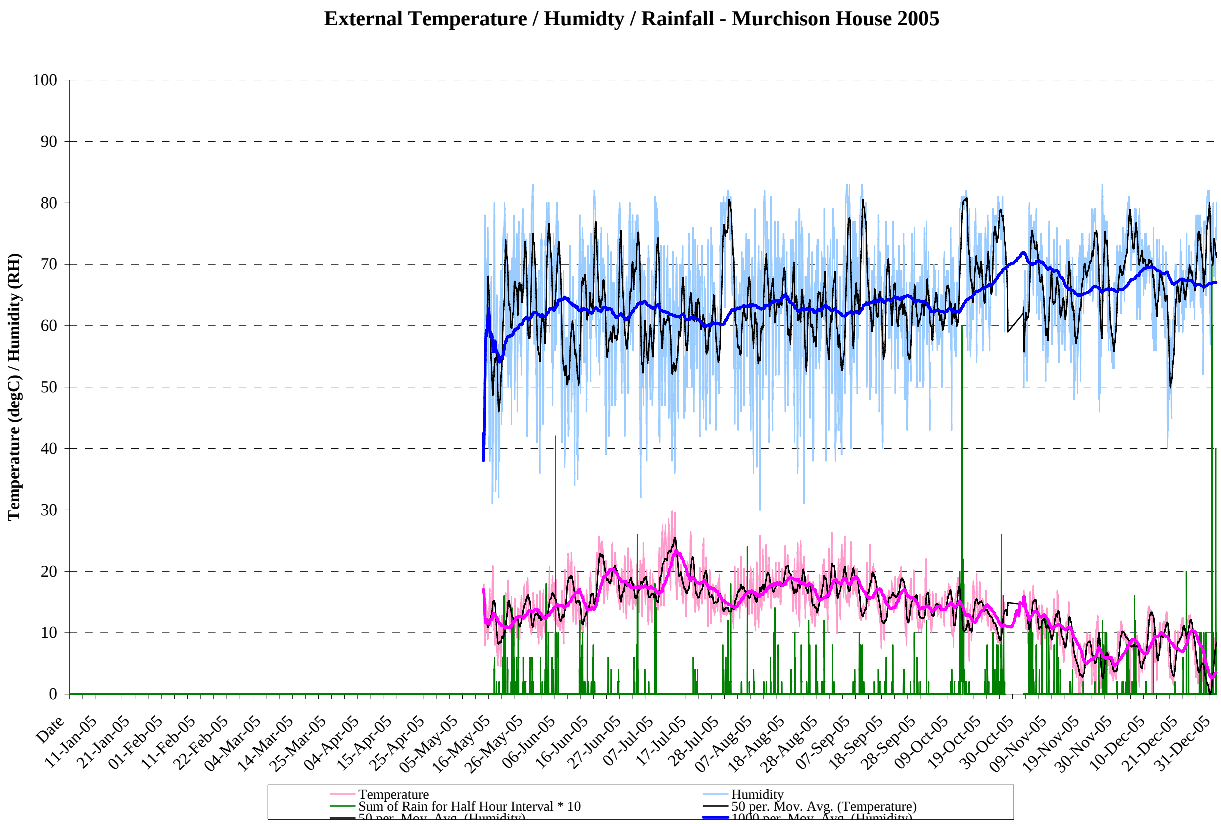

Figure 89: Weather Murchison House, 2005

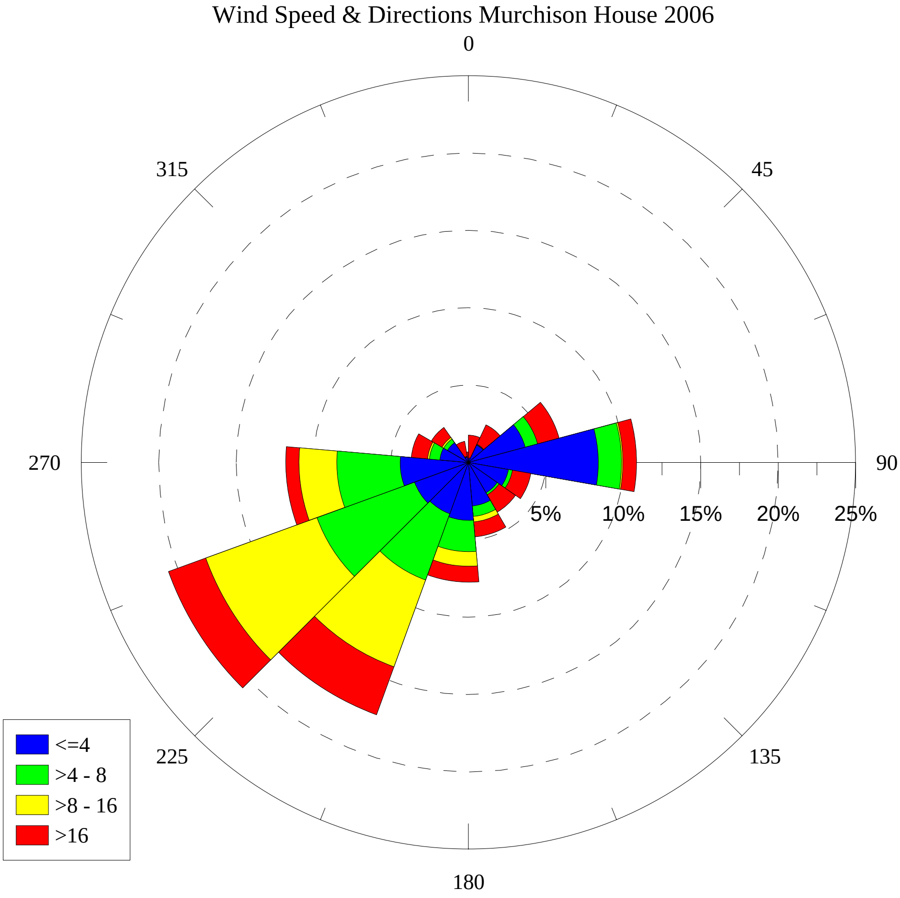

Figure 90: Wind speed/direction rose diagram Murchison House, 2006

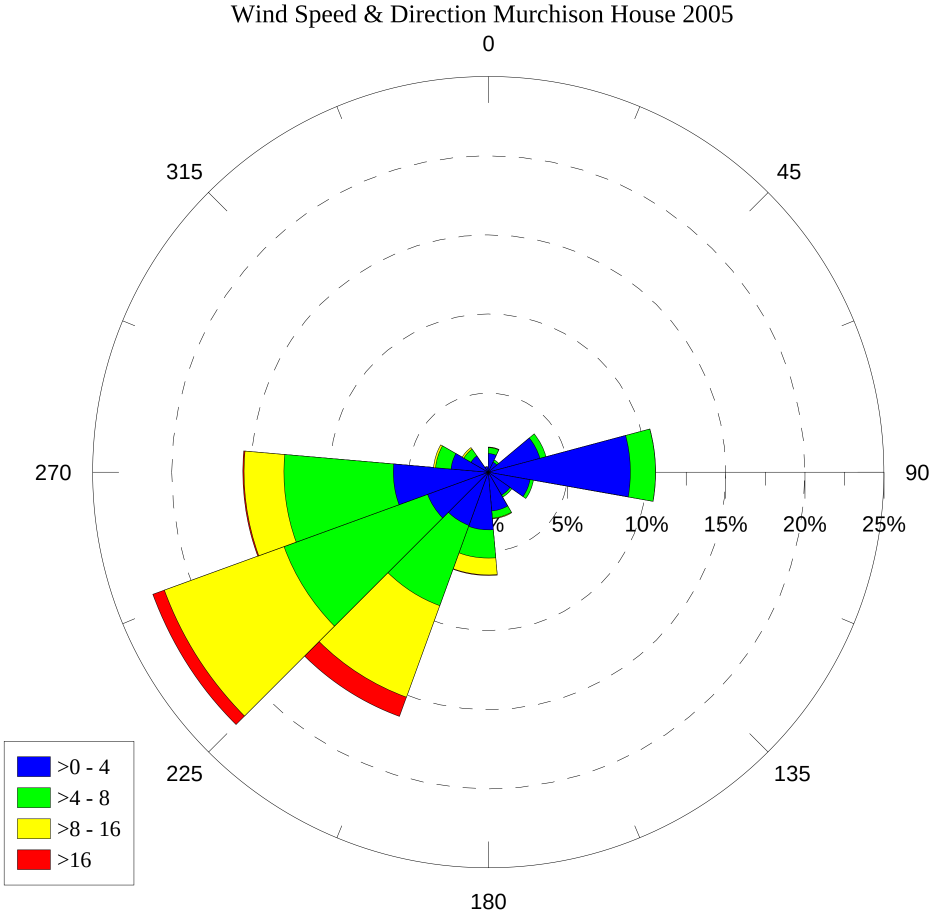

Figure 91: Wind speed/direction rose diagram Murchison House, 2005

3.6 MINI PROJECTS

3.6.1 Results of 2006 Mini-Projects

3.6.1.1 Damp Meter

The damp meter purchased in 2005 was used with varying success throughout the year. No readings were recorded although it can be reported that the damp noted in the mortar of the Petro Corner brickwork showed an improvement throughout the year, although there was an increase in December.

3.6.1.2 Short-term monitoring of Ancillary Data Store

As reported earlier the first delivery of loggers purchased for the core stores was rejected as the difference between the loggers was too high. On receipt of the newly calibrated instruments they were again placed in the Plastic tray to allow calibration to that logger to take place.

They were then used in a small data store to monitor the environment there. This was useful for two reasons: a short record of the store was gained and the stability of the loggers was observed.

Figure 92 shows the calibration of the loggers and the curves produced from the data store. The room does not have any heating and this is reflected in the results. It is cold and the humidity is high: essentially it is unsuitable for the storing of paper data.

3.6.2 Future Mini Projects

3.6.2.1 Monitor Differences in Open and Closed Aisles

This task has not yet been attempted but it is hoped that it will be carried out this year. The movement of the racks will be monitored and the data examined to determine if there are benefits in keeping the racks open or closed.

3.6.2.2 Continued Monitoring of 'Problem Corner'

Although there is no data logger in the corner at this time the area will continue to be monitored using the max/min instrument and damp meter. Decisions will be taken on the re-installation of the loggers and use of the dehumidifier will be taken depending on the results from these instruments.

3.7 RECOMMENDATIONS FOR EDINBURGH

- The recommendations laid down in the first report in this series will continue as they have proved to be robust.
- Areas identified, or suspected, as being problematic should have a logger or max/min monitor placed in them to study the conditions for a limited time to determine the condition of the environment and action taken to rectify any problems.
- This rationale will also be used for rooms being used as temporary stores. 'Mobile' loggers will be placed in them prior to data or samples. The measurements will be downloaded and interrogated as the area is being occupied and the loggers replaced and monitored for changes over the time of occupancy.
- The damp meter will be used to monitor the levels of moisture in wooden boxes and brickwork

- The dehumidifier settings will be changed routinely and the effect on the recorded environment noted. This will allow a strategy for this piece of equipment to be built.
- Collections continue to work closely with Facilities Management in identifying and resolving problems where possible. This proved successful in the past and is vital that it continues.

Unfortunately, what is becoming evident is that all the low-cost adjustments to working practices have been taken and to improve the environments within the stores further expenditure on equipment is now required. This is apparent from the increase in the temperatures and humidity recorded in the stores during 2006.

If the trend for warmer summers and wetter winters continues the alterations to working practices already in place are insufficient to establish stable environments within the stores without the installation of large air conditioning equipment.

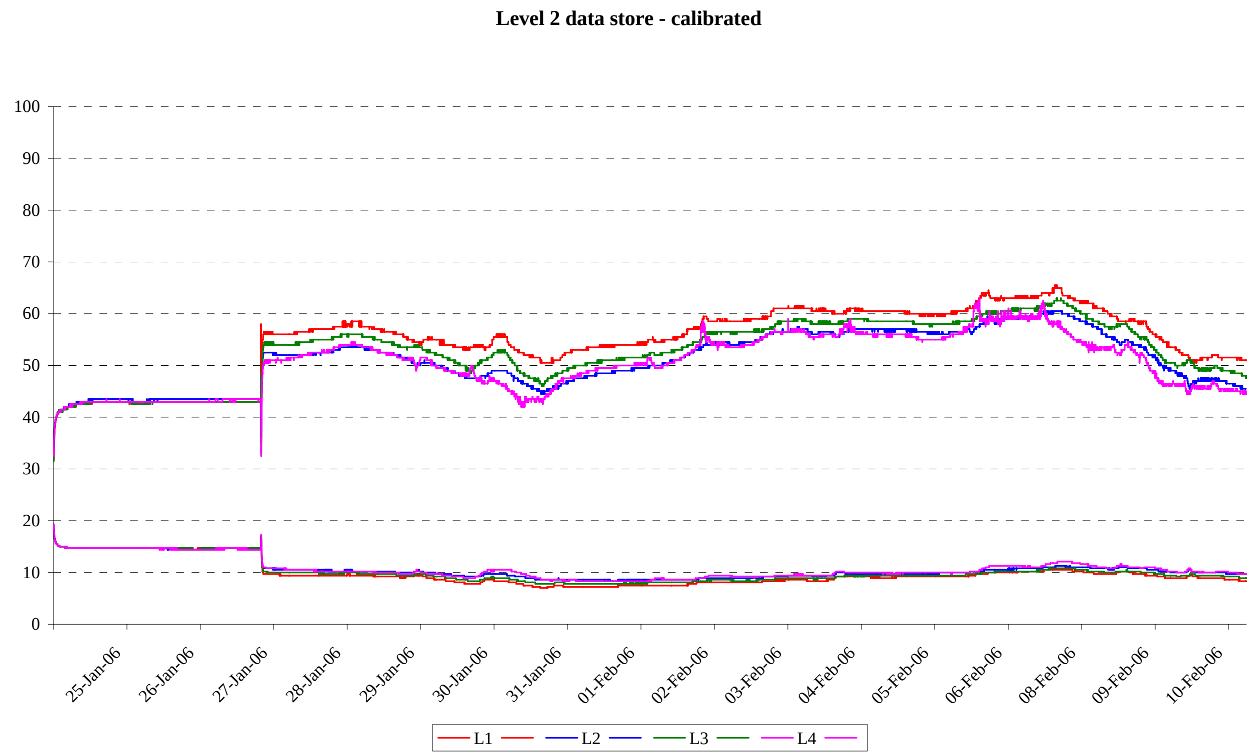

Figure 92: Calibrated data Jan 2006: Data store Murchison House

4 Conclusion

4.1 CONCLUSION FOR KEYWORTH

Monitoring of all existing areas within the Corporate Collections, NGRC and Library has continued during 2006. The monitoring within Jurassic Towers, SNS Server Room and a Museum wall cabinet has also been implemented.

During 2006, both floors of the museum have seen similar temperature readings within the recommended 16-22°C, with a 9% improvement compared to 2005, whilst weekly temperature cycles caused by the central heating are still visible during the spring. These cycles in theory could be eliminated if Facilities Management agreed to lower the central heating slightly, and to run the boilers continuously over the weekend. Additionally this may save money on running costs as the boilers do not have to work as hard during the beginning of the week. The humidity readings within the museum follow a similar pattern to the external values, especially during the summer months. This has not aided in the increase within the recommended 45-55% RH, which has only seen a slight increase in readings during 2006 to 23%.

The core store has seen a drop within the recommended temperature range for all areas, with the pallet store measuring the largest decrease. One factor is due to the increase in external temperatures, which has an effect on the fabric of the building. Whilst the tray store still has the highest readings in the summer due to its proximity with the metal roof. There have also been drops in temperature throughout the year resulting from the shutter door being open to allow for deliveries into the core store. Compared to 2005, acceptable humidity readings have improved by 9%, however the largest increases are in readings below the minimum 45%RH. The shutter door has affected areas within close proximity of the door. The variations will not be constant due to varying external conditions when the door is used or remains open for prolonged periods.

The conservation laboratory and main corridor in the core store has seen an improvement in temperature readings within the recommended range by 20% compared to 2005. However the shutter door in the core store has affected the readings in the laboratory due to the ventilation grill in the laboratory door. Humidity values that fall within the acceptable parameters have not seen a great improvement compared to last year; the largest rise being 6% in the laboratory. It is difficult to determine if the humidity experiment was successful at increasing humidity levels within the laboratory, as the main corridor in the core store showed similar readings. Perhaps caused by the shutter door being open, and air flowing through the ventilation grill in the laboratory.

The cold store is running efficiently at 99% of the time within the recommended range, even though the summer temperatures have been one of the hottest recorded, thus providing excellent storage conditions for this type of material.

For the museum sub-fossil bone specimens and mahogany cabinets, all of the areas are within their respective recommended temperature ranges for at least 72% of the time, whilst the wall cabinet readings amount to 91% within the recommended range. All monitors within the aisles have seen a slight decrease in values for their recommended ranges. Whereas the monitor within the museum cabinet has seen a decrease of 55% within the 45-55%RH recommended range. This would suggest that the humidity within the museum is affecting the readings. Further monitoring throughout 2007 will therefore be required. The monitors recording humidity for the sub fossil bone material within and outside of the cabinets are very similar. This is promising, as no additional controls have been installed to regulate the environment within the wall cabinets. It is difficult to conclude if the humidity experiment has improved the condirions around the larger sub fossil bone specimens. This experiment does show continuous levels of evaporation for all three areas; with the highest evaporation occurring during the winter months, when the central heating is operational.

All of the monitors within the NGRC fail to meet the recommended 16-19°C, however there has been a marginal improvement with these values, now equating to 2.8% of the recorded time. The humidity readings by comparison are very similar to those during 2005, with the strong room being within the recommended range for 58% of the time. Whereas data from the records room and storage boxes only comply with the recommended guidelines for a maximum for 17% and 20% respectively. This shows that the record boxes are buffering the surrounding environment to some extent. The strong room is however a better location for complying towards the BS standard 5454:2000 in humidity readings, but not in terms of the recommendations for temperature. Further measures must be taken to improve the temperature and humidity conditions within all areas of the NGRC in order to comply with the BS standard.

Measurements taken in Jurassic Towers have shown that this working environment suffers from high fluctuating temperatures throughout the year, during the summer as a result of the Sun heating the building and from the central heating system in the winter. Humidity values also vary greatly, affected by variations in external humidity. These findings would suggest that the building is poorly insulated and is not ideal as a working environment or for the storage of any future NGRC records.

The Library strong room currently meets with the British standard BS 5454:2000 for 75% for the time recorded within the 16-19°C temperature range and 63% of the time for humidity readings within 45-60%RH. This is an improvement on the figures from 2005; but it would be beneficial to try an increase the amount of time within the recommended parameters.

The SNS server room has seen an eight-month monitoring period. During which time the temperature readings next to the air conditioning unit are fairly constant around 21°C, where as the monitor adjacent to the server room does record greater fluctuations. This is due to temperature variations in the corridor caused by staff and contractors accessing this area.

Most of the areas monitored during 2006 do not fall within the acceptable recommended parameters for all of the time, except for the library strong room, SNS server room and cold store, which with air conditioning systems provide suitable conditions. It is becoming increasingly difficult to stabilize the internal readings partly because there has been one of the highest summer and autumn temperatures on record. Perhaps these elevated seasonal temperature patterns will become common occurrences in the future? The only way to tackle this problem is to invest in equipment to regulate temperature and humidity to within acceptable levels, rather than to make modifications to existing systems, which with future climatic change may not be enough. Until funding becomes available and new equipment is installed, it is imperative that all material is stored within boxes and trays wherever feasibly possible to minimise the effects of these climatic conditions.

4.2 CONCLUSION FOR EDINBURGH

The extension of the monitoring programme to include two remote core stores and, within Murchison House, the Library store and the SNS Server Room has increased the time required to collect the data, to prepare it for reporting and to present the data in this report. Fortunately this has been held to a minimum by utilising a new program, Escort Console by Escort Data Logging Systems Ltd. (EDLS), to interrogate the logger data.

Rather than having to open each file separately, save it as a comma separated file and then open and copy this file to an excel spreadsheet before uploading to the MSAccess table the new program allows multiple files to be opened and copied and saved to a single excel file with a minimum amount of scrutiny to ensure start times are correct.

The areas added in 2006 have been included as monitoring only and as such no intervening adjustments were planned. This allowed the data loggers to be primed to record such that the data need only be downloaded every 4-weeks. This has reduced the possible pressure on time at collection and presentation.

The extension of the recording areas has shown that none of the stores used to house the collections are fit-for-purpose.

The programme of monitoring the temperature and humidity is vital to the safe keeping of the specimens and has already highlighted and resolved a number of issues.

The improvements achieved in previous years have been cancelled out this year. This has been due to a combination of one of the hottest years on record (nationally) and also one of the wettest.

We have shown that in the extreme area of the Petro Corner which suffers from damp we can manage to a certain extent it by the use of a de-humidifier. It was hoped that a short period of drying out would rectify the problem but it has been shown that continual dehumidification is required.

Figure 74: 2005/2006 Temperature/Humidity target success comparison, Murchison House shows that only four sets of reading showed any improvement from 2005: Museum and Archive SW temperature and the Humidity in the North and East Petro Corners. That we can only control either the temperature or humidity, not both, indicates we cannot continue to improve without additional resources.

We have reached the stage where we have exhausted the improvements we can obtain through changes to working practices or through small environment control systems like the mobile dehumidifier in the Petro corner. The lack of environment control in the stores means that we will be more at the whim of the vagaries weather and if, as is thought, the weather continues to be hotter and wetter we will be unable to manage the environment within the stores to an adequate level.

Consideration should be given to the installation of environmental control systems.

The inability to successfully manage the Archive Room must be of some concern given that it is supposedly controlled by a computerised air conditioning system. The results of the monitoring have been brought to the attention of Facilities Management throughout the year resulting in service engineers being called. However it is apparent that urgent review of the system is required.

Comparison between the Loanhead and Gilmerton stores shows that, although Gilmerton is larger, the insulation it has and keeping external doors open to a minimum improves the environment within. This may be obvious but without major expense the Loanhead core store cannot be brought up to the standard of the Gilmerton building, which in itself is not ideal.

The shared facility at Loanhead, with the additional pressures on the environment caused by the use of the building is causing problems that cannot be rectified within the current building.

Appendix 1 Summary of the Strategy for Environmental Control

STRATEGY

1. Determine from appropriate sources (publications, meetings, personal communications, internal research, etc.) current best practice guidelines for the storage of the various materials types found within the NGMC. The guidelines should include the range and permissible variation of ambient temperature and of ambient relative humidity.

2. Routinely monitor temperature & Relative humidity in all storage areas, including conditions within typical trays, drawers, boxes and cabinets. Monitor external weather conditions where possible.

3. Review effects of room temperature and humidity on container temperature and humidity. Where the latter vary outside target limits, consider whether improvements can be made in the room parameters. Where temperature and/or Relative humidity readings indicate building/heating/ventilation defects, advise appropriate authorities.

4. Where trays or drawers vary outside these limits, microclimates must be used.

5. Implementation priority must be given to Museum Collection fossils and new borehole material.

PROCEDURES

Acceptable Temperature & Relative Humidity limits

1. Acceptable storage conditions for geological specimens (Doughty & Brunton, 1993)

Pyrite & Maracasite	16-22°C	<55% RH
Sub fossil bone, tusks, teeth	16-22°C	>40% RH
Fossils with shale/clay matrix	16-22°C	>40% RH
Paper data, including books	16-19°C	>45<60% RH

Storage Guidelines

2. All items should be stored in closed containers whenever possible.

3. Where pyritised fossils are to be stored in containers where humidity's may rise over 55%RH, they should be kept in microclimates, buffered with artsorb to 40%RH.

4. All pyritised fossils that have suffered pyrite decay should be stored in microclimates, buffered with artsorb to 40%RH.

5. Fresh borehole material, where organic or sulphide content is important, should be stored in barrier film, with Oxygen scavengers, in the cold store at 4°C.

Monitoring Guidelines

6. Monitor temperature and relative humidity readings on a regular basis, i.e. every 3 minutes, starting on the hour.

7. Monitors should be downloaded into a suitable digital format on a weekly basis.

8. Instruments used for monitoring purposes only should be read or downloaded on a monthly basis, the time interval between recording set to 30 minutes.

9. Where possible, monitors should be calibrated on a regular basis, i.e. at least once a year, or when new loggers are purchased, so they can be used as a benchmark.

Appendix 2 Keyworth Data

Adobe® Acrobat® version of this report.

2 Main Folders : 2005 & 2006

2005 has six main folders

30 Minute Extracted Data
- 14 sub folders for each locality monitored during 2005. All data calibrated and extracted to every 30 minutes.

Calibration Data
- Calibration period data in csv format
- Grouped data for both prior and after the calibration period.

Raw Data in csv format
- 14 Sub folders, for 2005
- Raw data in csv format, for each monitor.

Raw Data in lcf format
- 15 Sub folders for 2005
- Raw data in lcf. Format, for each monitor including the weather readings.

Report Images
- Report images used for 2005 report

Yearly Histogram data 2005
- Yearly histogram data for the main areas during 2005

2006 has seven main folders

30 Minute Extracted Data
- 14 sub folders for each locality monitored during 2006. All data calibrated and extracted to every 30 minutes.

Calibration Data
- Calibration period data in csv format
- Grouped data for both prior and after the calibration period.

Raw data from other projects
- Raw data in Excel format for Humidity Experiments, Jurassic Towers and SNS Server Room

Raw Data in csv Format
- 14 Sub folders, for 2006
- Raw data in csv format, for each monitor.

Raw Data in lcf Format
- 14 Sub folders for 2006
- Raw data in lcf. Format, for each monitor including the weather readings.

Report Images
- Report images used for 2006 report

Yearly Histogram data 2006
- Yearly histogram data for the main areas during 2006

Appendix 3 Edinburgh Data

Adobe® Acrobat® version of this report.

Four folders: -

2005 – two folders & 5 files

- Converted files Folder
  - 12 folders containing raw data in monthly folders in Comma Separated Value (csv) format (readable by MSExcel).
- Logger files Folder
  - 12 folders containing raw data in monthly folders in original format as downloaded from loggers (lcf format).
- 2004&05 comparison.xls (comparative graphs from Petro & Palaeo loggers)
- Bar graphs 04-05.xls (source spreadsheet for bar graph figures)
- Calibration 2005.xls (source spreadsheet for calibration figures)
- Internal & External.xls (Comparison between internal events & external environment changes)
- MH 30 Minutes 2005.xls (Calibrated/GMT adjusted data for the year in MSExcel format).

2006 – 2 folders

Murchison House 3 folders & 7 files

- Converted files Folder
  - 12 folders containing raw data in Comma Separated Value (csv) format (readable by MSExcel) in monthly folders.
- Logger files Folder
  - 12 folders containing raw data in original format as downloaded from loggers (lcf format) in monthly folders.
- Mini Project - Data Store Folder
  - 7 files of Data Store Mini Project data
- Bar Graphs 05-06.xls
- Calibration February 2006.xls
- Calibration June 2006.xls
- MH 30 Minutes 2006.xls (Calibrated/GMT adjusted data for the year in MSExcel format).
- Roof.csv (Roof calibration data)
- Roof.xls (Roof calibration data & curve)
- Whirling Hygrometer Archive Store data.xls

Out Stations 1 folder & 5 files

- Converted Files Folder
  - 12 folders containing raw data in monthly folders in MSExcel format.
- Cool Period Oct Nov 2006.xls
- July-Aug 06.xls
- New logger calibration - first batch.xls (calibration data for Loanhead & Gilmerton loggers. These loggers were returned for recalibration)
- New Loggers Jan 06.xls (calibration data for Loanhead & Gilmerton loggers)
- Out_stations_30_minutes 2006.xls

Access Files

- All environment data.mdb - Store room data
- MH Met data - 2005.mdb - Weather station data for 2005
- MH Met data - 2006.mdb - Weather station data for 2006

Met Data – 2 folders & 1 file

- 2005
  - 30 minute Met Data 05.xls

    (Due to pressure of space on this CD no original Met data has been provided)
  - Wind Speed Data 2005.xls – all wind speed measurements for 2005
  - Wind Speed & Dir 2005.emf (image of rose diagram of wind speed & dir 2005)
  - Wind Speed & Direction 2005.grf (rose diagram of 2005 data: Grapher™ Six file)
- 2006
  - 30 minute Met Data 06.xls

    (Due to pressure of space on this CD no original Met data has been provided)
  - External Temp Humidity Jul Aug 06.xls
  - Wind Speed Data 2006.xls – all wind speed measurements for 2006
  - Wind Speed & Dir 2006.emf (image of rose diagram of wind speed & dir 2006)
  - Wind Speed & Direction 2006.grf (rose diagram of 2006 data: Grapher™ Six file)
- Loanhead Aug 98.xls

Glossary

BGS - British Geological Survey

BST - British Summer Time

CSV - Comma Separated Value (file) .csv

GMT - Greenwich Mean Time

LCF - Logger Compact File .lcf

NGRC - National Geological Records Centre

RH - Relative Humidity

MTA - Murchison House Weather Station, Temperature readings, .MTA

MHU - Murchison House Weather Station, Humidity readings, .MHU

SNS - System & Network Support

TNA - The National Archives

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