Pan American Health Organisation
Emergency Preparedness and Disaster Relief Coordination Programme
Barbados

Vulnerability Assessment - Phase II
of the
Karl Heusner Memorial Hospital

Belize City, Belize

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Consulting Engineers Partnership Ltd

September 2001

Vulnerability Assessment - Phase II
Karl Heusner Memorial Hospital, Belize City, Belize

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1 INTRODUCTION

Located on level, low-lying ground, the new Karl Heusner Memorial Hospital in Belize city is the only referral hospital for the country of Belize. The Hospital was designed and constructed in the 1990s and consists of single and two-storey buildings *(Photos 01, 02 & 03; Appendix II)*.

The Pan American Health Organisation's Emergency Preparedness and Disaster Relief Coordination Programme (PAHO-PED), through Dr Dana van Alphen, engaged Tony Gibbs to:

> Make a visit of inspection to the Hospital in November/December 2000. The visit consisted of:
>
> a examination of areas accessible without destructive "surgery";
>
> b examination of a sample external wall panel subjected to invasive "surgery" in an area acceptable to the authorities;
>
> c discussions with the local authorities about the feasibility of incorporating some of the mitigation measures (arising from this vulnerability survey) in the present European Union Rehabilitation Project.

With respect to item c, it was decided during the visit that it would not be appropriate to pursue the EU option any further at this stage.

This second phase of the Vulnerability Study of Belize Hospital was limited to the following areas of the Hospital:

accident and emergency department
operating theatres
wards (to provide 50 "safe" beds)
maternity
pharmacy

and the following services:

water
electricity
medical gases

A formal analysis of the structure was not required.

A local consultant, Burrell-Burrell Associates, was involved in this assignment (as contracted by others) to provide on-the-spot assistance. In preparation for the December visit Tony Gibbs:

- provided a brief for the local consultant's involvement (see Appendix III);
- provided PAHO with the programme for the visit (see Appendix III).

2 HAZARDS

2.1 General

The primary natural hazards facing Belize are:

(i) earthquakes

(ii) hurricanes

(iii) torrential rains

2.2 Earthquakes

Seismic events in Belize are principally associated with the Cayman Fracture Zone which extends eastwards from Honduras to Hispaniola and forms the boundary between the Caribbean and North American Plates in this area and is a tectonically active feature along which future seismic events may be expected. The Swan Fracture Zone (between the Cayman Trough and Honduras) is a strike-slip fault intersecting the mid-Cayman Rise about 200 km south of the Cayman Islands and is a transform fault. This is also known as the *Sistema de fallamiento Polochic-Motagua*. The northern side of the fault is moving westwards at about 25 mm per year relative to the southern side of the fault. *Figure 1* in *Appendix I* illustrates the tectonic setting in the vicinity of Belize.

The Caribbean Uniform Building Code (CUBiC) recommends a Z-factor of 0.75 for areas of Belize within 100 kilometres of the southern border, *ie* including San Antonio and Punta Gorda but excluding Middlesex, Pomona and Stann Creek. For the rest of Belize (including Belize City, the recommendation in CUBiC is a Z-factor of 0.50. This is the document which has been adopted by reference for earthquake loads in the Belize Building Standards, published in 1999.

2.3 Hurricanes

Belize lies in the North Atlantic Ocean, one of the six main tropical areas of the earth where hurricanes may develop every year. A general historical record of those hurricanes (and tropical storms) affecting Belize from the eighteenth century to 1979 is given in a table at the end of this sub-section. Since 1979 the following hurricane events were significant in Belize:

Tropical Storm Hermine - 22 September 1980
Tropical Storm Bret - 18 August 1993
Hurricane Mitch - 1998
Hurricane Keith - 2000

Wind speeds over Belize from a Category 3 hurricane are illustrated in *Figure 2* in *Appendix I*. Associated storm surge is illustrated in *Figure 3* in *Appendix I*.

The destructive potential of a hurricane is significant due to high wind speeds, torrential rains (which produce flooding) and storm surge (with potential heights of several metres above normal sea level).

The Caribbean Uniform Building Code (CUBiC) sets out the basic wind parameters for the design of buildings in Belize. The normal requirement is the 1-in-50-year wind, *ie* a wind speed which on average is not expected to be exceeded more than once in 50 years. In the country of Belize this produces basic 3-second gust wind speeds between 45 and 54 metres per second (m/s). For a critical health-care facility, it is appropriate to adopt a wind speed which on average is not expected to be exceeded more than once in 100 years. This would be 61 m/s (3-second gust) for Belize City. This translates to a CUBiC (100-year) reference pressure of 1.00 kilopascals (kPa), based on a 10-minute average wind speed. CUBiC is the document which has been adopted by reference for wind loads in the Belize Building Standards, published in 1999.

2.3.1 Catalogue[1] of Hurricane Events in Belize

The dollar values have not been adjusted for inflation. The reported frequency of events is clearly very dependent on the degree of post-Columbian, European involvement in the territory. (The documented history of Belize in past centuries is in proportion to the degree of European settlement in those periods.)

1700-1800

1787 September 23 severe; great damage; many lives lost

1800-1900

1813 ??? ??

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[1] Compiled by CDPS Information Exchange, February 1980. Main sources – José Carlos Millas, Ray Tannehill, US Weather Bureau, CDPS, OFDA

1827 ??? ??	
1831 ??? ??	
1864 August 31	town inundated

1900-1979

1901 Jun19-Jul01	may have been affected by modest hurricane
1918 August 21-25	may have been affected by a storm
1921 June 18	
1922 June 13	floods from torrential rains
1931 September 10	1500 fatalities; damage totalled M$7.5
1932 Sep26-Oct03	entered Mexico near British Honduras[2]
1934 June 04-21	crossed British Honduras before reaching hurricane force
1942 November 08	9 deaths; M$4 damage
1945 October 02-04	great destruction
1954 September 27	slight damage
1955 September 28	(Janet) 16 killed; M$5 damage
1960 July 15	property damage slight; heavy damage to crops
1961 July 24	(Anna) considerable damage at Punta Gorda
1961 October 31	(Hattie) very severe in Belize and Stann Creek; 262 fatalities; M$60 damage
1964 November 09	tropical storm in dissipating stages
1969 September 03	flooding from torrential rains
1971 August 25	
1971 September 11	
1971 November 21	
1974 September 19	high tides and heavy rain
1977 October 18	tropical storm
1978 September 19	4 deaths

2.4 Torrential Rains

Although hurricanes are often accompanied by heavy rains, severe rainfall events resulting in flooding in Belize are also, and frequently, associated with troughs and tropical depressions. The risk of flooding is therefore not restricted to, nor more likely to occur during, hurricane events.

Drainage systems and structures in Belize are generally designed for rainfall events having return periods of the order of 25 years. This means that such systems are likely to become overloaded and cause some degree of flooding when rainstorms are experienced with return

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The name for the colony before becoming independent Belize periods greater than 25 years. The Belize Building Standards, published in 1999, do not prescribe rainfall intensity-duration-frequency criteria.

Generally, lower lying areas will be more susceptible to flooding than higher and sloping ground. Such is the condition in most of Belize City.

The damage caused by flooding depends on the type and elevation of facilities in the location. The results of flooding may range from the inconvenience of temporarily submerged driveways to the loss of equipment and finishes inside flooded buildings and consequential disruption of the functions.

3 INVESTIGATION PROCEDURE

3.1 General

In October 2000 Tony Gibbs made his first visits to the Karl Heusner Memorial Hospital (KHMH). The report of those visits was submitted on 23 November 2000.

Prior to the November/December visit to Belize, Tony Gibbs submitted an overall programme for the visit *(Appendix III)* to PAHO (Belize and Barbados) as well as the specific requirements for the intended investigations of sample wall panels at KHMH *(Appendix III)*.

The dates during which Tony Gibbs was in Belize were from 28 November to 02 December 2000. The field investigations were carried out after consultation with the Acting Head of the National Engineering and Maintenance Centre, Mr Fred Smith[3] *(Photo 04)* and Elvis Novelo, also of the NEMC.

Other persons met during the visit were: Dr Graciela Uriburu (PAHO Representative, Belize); Dr Claude de Ville de Goyet (PAHO, visiting from Washington); Dr Amalia del Riego (PAHO, Belize); Dr Dana van Alphen (PAHO, visiting from Barbados); Permanent Secretary Henry Anderson (Ministry of Health & the Public Service); Dr Errol Vanzie (Director of Health Services); Dr Rosado (CEO, Hospital Administration); Francisco Gonzalez, Cuthbert Burrell[4] and Paul Satchwell[5] (all of Burrell-Burrell Associates); Kevin Herrera[6] (Belize

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3 Tels (W): 30511; (H): 34455

4 Tels (W): 24750; (H): 35375; (C): 014 8582

5 Tels (W): 24770; (H): 70480; (C)· 014 6555

6 Tels (W): 02-73148; (H): 02-45690

Chamber of Commerce & Industry); Yolanda Crombie[7] (ORINCO[8]).

A summary report on the November/December visit was submitted to PAHO on 15 December 2000 *(Appendix III)*.

3.2 Desk Studies

3.2.1 Documents

Drawings of the construction of KHMH are available in Belize and were examined. There is evidence that these drawings do not reflect the "as-built" condition of the Hospital in several important respects. Because of this, some caution must be exercised in interpreting and relying on the drawings in areas where it is not feasible to confirm (or otherwise) the accuracy of the "as-built" documentation. As an example of this, *Figure 4* in *Appendix I* shows the intended construction of the suspended slabs for the hospital. What is illustrated is a ribbed, hollow-pot slab. The ribs are precast, probably prestressed concrete. The infill pots seem to be of clay. Then there is an in-situ concrete topping. In actual fact the built floor is an in-situ, ribbed, concrete slab *(Photo KHMH-14, Appendix II)*. Although both systems can be equally satisfactory, they are nevertheless substantially different in their details.

Once again the unavailability of as-built drawings has rendered difficult the satisfactory review of a facility. The importance of obtaining and archiving a comprehensive set of "as-built" documents cannot be over-emphasized.

3.2.2 Earthquake-resistant Design

There are a number of conceptual guidelines which can be followed to ensure that buildings and ancillary items offer adequate resistance to earthquakes. Although deviation from the following rules will not necessarily result in an unsafe structure, the basic principles are well-grounded in the observed performance of buildings impacted by earthquakes. Ideally, buildings should be:

(i) symmetrical;

(ii) subdivided into rectangles if the overall functional arrangements call for **L**-shaped, **T**-shaped, **U**-shaped or **H**-shaped plans.

(iii) not too elongated in plan (with an aspect ratio less than 3);

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[7] Tel (W): 02-32657

[8] Organisation of Insurance Companies of Belize

(iv) continuous and monolithic, with a uniform strength distribution;

(v) designed so that vertical members will remain intact after horizontal members have "failed" or yielded;

(vi) designed so that columns and walls are continuous from foundations to roof;

Features such as projecting towers, abrupt changes in section of structural elements and offset columns and beams should be avoided.

Non-structural items such as infill panels, windows, doors, suspended ceilings, services and fixtures also require careful consideration. Inappropriate detailing of stiff, infill panels could lead to premature failure of surrounding structural elements and/or the panel itself.

Similarly, windows and door frames should ideally be so detailed so as to lessen the chance of damage to the glass or the jamming of doors. In the case of services, excessive displacements could result in damage to pipes or other critical utility lines. Where possible, flexible joints should be used.

The subject facility contains some of the inherent weaknesses mentioned above. The most critical issues were:

(i) the presence of unfavourable plan shapes (**L**-shaped, **T**-shaped, **U**-shaped or **H**-shaped) - *(Figure 5, Appendix I)*

(Where divisions were provided *(Figure 6, Appendix I)*, the joints were generally of inadequate widths and were not always continuous from the top of the foundations to the roof top.)

Photo 05 shows a joint in the floor (Operating Theatre) whereas the joint is not continued in the contiguous wall and the corresponding ceiling. The wall consequently exhibits a fine crack, faintly visible in *Photo 06.*

Photo 07 shows a joint in the floor (corridor leading to the Laundry and the Kitchen) whereas the joint is not continued in the contiguous wall and the corresponding ceiling. The wall consequently exhibits a significant crack, clearly visible in *Photos 08 & 09.*

There is no joint at the right-angle junction of the two walls in *Photo 10.*

(ii) elongated plans *(Photo 11)*

(iii) relatively stiff main storey and upper storey supported on the sub-storey consisting of columns not restrained (as above) by in-fill, block-wall panels *(Photos 12 & 13)*

(iv) vertical members (columns) which are weaker than the adjacent horizontal members (beams)
(Photo 13)

(v) one-way structural system with beam-and-column frames in one direction and only ribbed slabs in the orthogonal direction *(Photo 14)*

3.2.3 Hurricane-resistant Design

Although there have been instances of block walls being blown over in hurricanes, adequately reinforced and tied wall panels usually perform well. Lightweight roof structures are generally the cause of greater concern. Single-ply and multiple-ply membranes require adequate holding-down details. These details are usually a combination of adhesives and discrete fasteners. Glazed openings in the building envelope and external doors are areas of inherent vulnerability. The most critical issues were:

(i) the use of gravel as ballast for the waterproofing membranes
(Gravel is likely to be dislodged by high winds and act as missiles which would damage adjacent parts of the facility as well as neighbouring buildings.)
(Photo 15)

(ii) the waterproofing membranes which are not identifiably secured to the concrete slabs to prevent removal by hurricane winds

(iii) the windows which are not supplied with built-in shutters and which are not made of impact-resistant glass and are therefore vulnerable to damage by flying debris during hurricanes *(Photo 16)*

3.3 Site Inspections and Interviews

As stated in Section 3.1, visits were made to the site. A number of photographs were taken and these form a major part of this report. These photographs are included in *Appendix II.*

Inspections were limited to the superstructure and its ancillary fixtures, and to equipment vital to the maintenance of the Hospital's operations. No specific examination of foundations has been undertaken; in the absence of geotechnical information this would require a much more intensive site investigation. It should be realized, however, that the type and condition of the foundations and the characteristics of the underlying soil will have a significant influence on the effects of earthquakes on the buildings.

Interviews were conducted with (or there were brief meetings with) the various persons mentioned in Section 3.1.

Information on the history of the building and on its performance during (and before) Hurricane Keith[9] in October 2000 was obtained from some of the above-mentioned persons.

3.4 The Building

3.4.1 The Main Structure

The conceptual issues are dealt with in Sections 3.2.2 and 3.2.3 above.

3.4.2 Ceilings

These components are vulnerable to earthquake damage if not securely fastened. In such conditions ceilings are liable to fall, causing injury and unnecessary inconvenience.

Photos 17 & 18 show the arrangement of ceiling supports in most of the Hospital. It is not a clear, uniform and tidy arrangement. There are good areas and unsatisfactory areas. *Photo 19* shows one of the hanger supports for the ceilings. The twisted arrangement could work loose during earthquake shaking.

Photos 20 & 21 show ceiling panels about to fall, even without an earthquake. *Photo 22* shows a ceiling panel left, presumably by maintenance staff, in a precarious position. In the background there are other missing panels to be seen.

Damage caused by Hurricane Keith to external ceilings can be seen in *Photo 23*. It is understood that some of the internal ceilings were damaged by water leaking through the roof, presumably during Keith, as well as by leaking airconditioning ducts.

The Delivery Room 2 has a gypsum plasterboard ("sheet rock") ceiling. It is unknown how this is fastened. Such ceilings are relatively heavy and require correspondingly strong supports to prevent them falling due to the vertical accelerations during earthquakes.

In the Maternity Ward (25 beds) many of the ceiling tiles had been removed.

3.4.3 Egress

Some of the emergency exits were locked during the site visit (*eg* in the Paediatric Ward - 25 beds). This defeats the purpose of such exits. An example is in *Photo 24*.

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9 Hurricane Keith was a hurricane in the off-shore islands. In Belize City the event was measured as a tropical storm only.

3.4.4 Mobile Equipment

Many pieces of equipment in hospitals are wheel-mounted. Wheels are usually provided with brakes or clamps. These brakes should be activated whenever the equipment is not in the process of being moved. Some of the pieces of equipment in *Photos 25, 26 & 27* were not provided with wheel clamps. *Photo 28* shows an example of a very convenient mechanism, clearly designated, for providing restraint against rolling.

Gas cylinders must always be restrained against toppling when not being moved. *Photos 25, 26, 29 & 31* all show unrestrained cylinders.

3.4.5 Shelving

Shelves should be designed so as to inhibit contents from falling during earthquakes. This could be achieved by raised edges, straps or "egg-crate" shelves. *Photos 30 & 31* illustrate the problem.

3.4.6 Drainage

At the low-lying site of KHMH storm-water drainage poses a great challenge. Pumping is an option with significant cost implications. *Photo 32* illustrates the problem.

3.5 The External Block Walls

3.5.1 Preambles

During the visit in October 2000 an initial assessment was made of the vulnerability of the Hospital, and the tender documents for the European Union (EU) Rehabilitation Project were reviewed. The initial assessment led to several questions, including the security of the external block walls which exhibited widespread cracking. Indeed these walls were one of the issues already being addressed by the EU project.

The examination of the "as-built" drawings of KHMH revealed no evidence of reinforcement in block walls. The parties involved with the EU project were not able to confirm the presence of reinforcement. Therefore, it was decided to carry out on-site investigations of samples of the walls. This was done on 30 November and 01 December 2000 with the assistance of Burrell-Burrell Associates.

3.5.2 Field Investigations

The particular places used for investigative surgery were chosen at random from those areas of the Hospital which would not disrupt unduly the operations of KHMH *(Photo 33)*. The team *(Photos 34 to 37)* executing the surgery was led by Kevin Parks. The first area investigated was in the link corridor midway between columns *(Photos 38 & 39)*. The second area investigated was also in the link corridor adjacent to a column *(Photos 40 to 45)*. The third area investigated was in the Maintenance Room (south-west corner of KHMH) at mid-level of the wall *(Photos 46 to 49)*. The fourth area investigated was also in the Maintenance Room at the top of the wall were it meets the capping beam *(Photos 50 to 52)*.

In no case was satisfactory reinforcement of the block walls found during the investigations. A few pieces of reinforcement were seen, however:

a in some cases the reinforcement was placed in block cavities without any grout or mortar, thus rendering the reinforcement worthless *(eg Photos 42 to 45)*;

b in some cases where the cavities were grouted the reinforcement was discontinuous, and thus ineffective *(eg Photos 46 & 48)* - vertical bars located in the Maintenance Room stopped just above window-sill level;

c in some cases where the horizontal reinforcement was intended to tie the block wall panel to the adjacent column the reinforcement did not penetrate the column, thus rendering the tie ineffective *(eg Photo 44)*;

d in most cases there was no reinforcement in the block cavities whatsoever *(eg Photos 39, 47 and 50 to 52)*;

e in no case was there any horizontal masonry reinforcement laid in the face shells of the blocks *(eg Photos 46 to 49)*.

In summary, one would have to regard the walls as being unreinforced.

3.5.3 Design Standards

The natural hazards design criteria for buildings such as the KHMH are listed in the Belize Building Standards published by The Belize Chamber of Commerce and Industry in the years 1999/2000[10]. They are:

- Wind Loads in accordance with the Caribbean Uniform Building Code (CUBiC) Part 2 Section 2 giving a reference pressure for the north part of Belize of 0.78 kilopascals (about 120 miles per hour - 3-second gust);

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[10] A discussion with Phillip Andrewin (tel: 31872), President of the Belize Association of Professional Engineers, revealed that the existence of the Belize Building Standards published by The Belize Chamber of Commerce and Industry was not common knowledge among engineers in Belize. Communications with Cadet Henderson (tel/fax: 08 22690; cel: 014 5425), Chief Engineer at the Public Works Dept, indicated that the use of the said Standards was not yet mandated in Belize.

- Earthquake Loads in accordance with the Caribbean Uniform Building Code (CUBiC) Part 2 Section 3 giving a zone factor for the north part of Belize of 0.5 (about 50% of the severity of, say, most of California).

CUBiC was published in 1985 and could reasonable be expected to have guided the design of the KHMH.

3.5.4 Vulnerability of Walls to Natural Hazards

For the CUBiC criteria stated above, the external walls of the KHMH require reinforcement. It is common for unreinforced masonry walls to fail during earthquakes. The failure of such walls during hurricanes is less common, but it does happen. Evidence of this can be seen in the below-referenced photographs which are to be seen on the final sheet of *Appendix II*:

- TG-011 - a warehouse after Hurricane David in 1979;
- TG-012 - an office building after Hurricane Hugo in 1989;
- TG-014 - a hospital after Hurricane Georges in 1998.

Reporting on the San Francisco de Borja Hurricane of 10-11 October 1846: 'the destruction was too extensive', concluded *Diario de la Marina*, 'to have been caused by a hurricane':

> "The number of those of us who believe that Havana also experienced an earthquake is considerable and to which (earthquake) we attribute the ruin of several walls ...., and not to the wind of a hurricane."

But the records do not show that there was an earthquake in Cuba during those days.

Further analysis was required to determine exactly for what levels of wind speed and earthquake shaking the KHMH walls would be safe. However, they are not demonstrably safe for the levels of hazards expected in Belize as articulated in the Belize Building Standards. Regrettably, the retrofitting of these walls will be neither convenient nor inexpensive.

Further consideration should be given to the external block walls. It would be worthwhile reviewing the problem panel by panel. The retrofitting of the panels will vary in difficulty, convenience and cost. In the most favourable circumstances it would not be too difficult and should be contemplated, even as a short-term programme. The aim is to make the hospital safe, not only for the 2001 season, but for its entire future life. If the Ministry wishes to proceed with the retrofitting of the external walls, a procedure could be set out the to guide the local consultants, Burrell-Burrell Associates.

This report does not include the details of retrofitting. It includes generic recommendations in Section 4.2 below. The details for retrofitting could be prepared by the local consultants under external guidance, should that be desired, as part of the implementation project. This is the usual way.

All of this is not meant to discourage the retrofitting. It is meant to indicate that retrofitting is necessary and that considerable work would be required. That considerable work includes comparative studies of different retrofitting methods as well as the physical work on site. Indeed, the way to reduce the physical work on site is to devote more effort to the comparative studies.

3.5.5 Analysis of the Walls for Wind Forces

The question "what wind speed could the walls withstand?" is interesting . At present it is understood that the Ministry's plan requires that the Hospital be evacuated when an approaching hurricane is likely to have winds in excess of a "certain speed". This has to do with storm surge[11]. That "certain speed" is not presently known with certainty. If it could be established, the walls could then be checked for that speed on the assumption that, were the walls to be breached only when the hospital is out of use, the disaster would be less. Such a scenario does not, of course, deal with the earthquake hazard.

The external walls of the hospital were analysed using the dimensions provided by Paul Satchwell of Burrell-Burrell Associates. Four cases were examined:

1 upper floors, internal panels (height 3.8 metres)

2 lower floors, internal panels (height 3.8 metres)

3 upper floors, end panels (height 4.7 metres)

4 lower floors, end panels (height 4.7 metres)

The assumptions are:

a no effective reinforcement in the walls (slightly conservative)

b panels supported laterally at floor (or roof) levels only (*ie* ignoring column supports) (somewhat conservative)

c no assistance from plaster finishes on the outside of walls (slightly conservative)

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Information on heights above mean sea level obtained from Burrell-Burrell Associates is as follows: ground - 1.2 to 1.5 metres; ground floor of KHMH - 3.0 m; Cat-2 storm surge - 2.0 m; Cat-3 storm surge - 4.0 m.

d walls built to a reasonable standard as unreinforced masonry (somewhat generous)

e the dimensions provided by B-BA are of the wall panels only and do not include the adjacent beams

For cases 1 and 2, the safe wind speed was calculated to be 69 miles per hour (3-second gust) or 56 miles per hour (1-minute sustained).

For cases 3 and 4, the safe wind speed was calculated to be 63 miles per hour (3-second gust) or 51 miles per hour (1-minute sustained).

These are strong tropical storm winds, less than Category-1 hurricanes.

Because three of the five assumptions are on the conservative side, one may wish to add a maximum of 10% to the wind speeds (*ie* an increase of 21% in wind pressures). That would give the following revised figures:

For cases 1 and 2, the safe wind speed would be 76 miles per hour (3-second gust) or 62 miles per hour (1-minute sustained).

For cases 3 and 4, the safe wind speed would be 69 miles per hour (3-second gust) or 56 miles per hour (1-minute sustained).

These are still less than Category-1 hurricanes.

It cannot be guaranteed that the walls will fail at these wind speeds. Likewise, it cannot be guaranteed that they would be safe. Using conventional engineering principles, the walls are not satisfactory for Category-1 hurricanes.

There are several uncertainties in determining the load capacity of existing concrete block walls. These uncertainties are on both the loading side and the strength side, expressed in terms of the modulus of rupture (MoR). The MoR is affected by the following:

- Type of mortar (amount of lime)
- Cement type
- Curing method
- Surface conditions of the blocks
- Initial rate of absorption of the mortar by the blocks

- Age, loading history, *etc*
- Quality of construction

Little is known about the above seven characteristics of the block walls at KHMH. In these circumstances, and having regard to the importance of these walls to the functioning of the Hospital, caution is advisable.

4 CONCLUSIONS & RECOMMENDATIONS

4.1 General

The facilities are generally in poor condition. There is evidence of inadequate maintenance and premature dilapidation. The refurbishment of the building is clearly necessary. In addition, there are several areas where the building is not adequate to withstand the levels of natural hazards anticipated by the Belize Building Standards. There is also the fundamental and intractable problem of the unfortunate location of the Hospital. Lastly, there is the need to sensitise the staff at the Hospital to the various non-structural vulnerabilities which could be alleviated without much physical effort.

The Hospital was designed and constructed as one project. It is reasonable to assume that the standards of design and construction were similar for all of the wards and buildings. This study was to focus on the following areas: accident and emergency department; operating theatres; wards (to provide 50 "safe" beds); maternity; pharmacy; water; electricity; medical gases. The results of the investigations, as articulated in this report, can be taken to apply to all of these areas. The importance of identifying these specific areas is that priority should be given to retrofitting these critical areas for the functioning of the Hospital during, and immediately after, a natural hazard event.

Generally, remedial work can be divided into short-, medium-, and long-term objectives.

4.2 Short Term

These items should be completed within one year:

(i) Implement most of the works forming part of the European Union Rehabilitation Project, with recommended amendments as set out in the Review document by Tony Gibbs dated November 2000[12]. The areas covered by the EU project and recommended here for short-term action include:

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[12] Karl Heusner Memorial Hospital, Belize City
Natural Hazards Vulnerability Assessment, Review of European Union Rehabilitation Project Designs
Tony Gibbs, Consulting Engineers Partnership Ltd, November 2000

roofing and waterproofing; courtyards and enclosures; the Technical Building; air-conditioning; boiler works; drainage works; electrical works; fire alarm; plumbing works and water distribution system.

(ii) Detailed check followed by the securing of all ceiling structures and ceiling panels throughout all relevant buildings.

(iii) Retrofitting of all shelves and cupboards in accordance with the "Guidelines for Vulnerability Appraisal and Reduction in the Caribbean" published by PAHO in the year 2000.

(iv) The training of Hospital staff so as to achieve better awareness of natural hazard mitigation measures, with particular reference to non-structural vulnerability. The issue of mobile equipment is central to this exercise. Here again, the document referenced in (iii) above is relevant. Better management of emergency exits should form part of this training.

(v) Carry out comparative studies for the retrofitting of all external walls and for internal masonry walls. These studies should address effectiveness of retrofit method; convenience of method; cost of method. Methods would include, but not be limited to: ferro-cement applications on both faces of walls; ferro-cement applications on a single face of walls; internal reinforcement in discrete bands; internal reinforcement by insertion of steel rods and grouting; external bracing; complete wall replacement.

(vi) Institute a clearly-articulated policy for all future capital and maintenance works with respect to standards and procedures. Guide documents would include the Belize Building Standards referenced in Section 3.5.3, the document referenced in (iii) above and the DIPECHO document of July 2000[13]. In addition, review consultants[14] should be employed for all major capital works projects.

4.3 Medium Term

These items should be completed within five years:

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Health Services Facilities in the Eastern Caribbean
Terms of Reference for Consultants and Standards (with particular reference to Natural Hazards)
Prepared for the Pan American Health Organization under the Disaster Prevention, Mitigation and Preparedness Programme of the European Community Humanitarian Office
by Tony Gibbs, Consulting Engineers Partnership Ltd, July 2000

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similar to the *bureaux de contrôle* in Martinique and Guadeloupe

(i) The retrofitting of all walls in accordance with the method selected from the process described in 4.2(v)

(ii) Provision of supplementary hardware to secure external doors against hurricane winds

(iii) Installation of weather-proof, impact-resistant glazing as replacements for all windows

Alternatively, installation of shutters fixed permanently to the walls

(iv) Installation of a recording anemometer on the premises of the Hospital in accordance with the advice of the National Meteorological Service in Belize for wind speed and wind direction measurements

(v) Installation of a recording rain gauge on the premises of the Hospital in accordance with the advice of the National Meteorological Service in Belize for rainfall intensity-duration measurements

(vi) Installation of three strong-motion accelerographs on the premises of the Hospital in accordance with the advice of the Seismic Research Unit (or other competent body) to record base ground motions and structural responses in earthquakes

4.4 Long Term

These items should be completed within ten years:

(i) Carry out a detailed analysis of the buildings for earthquake forces. Inevitably this will indicate the desirability of implementing retrofitting actions.

(ii) Rationalise the existing separation joints and introduce new joints to divide the buildings into a series of compact rectangles.

(iii) Strengthen the sub-ground-floor "soft storey".

(iv) Strengthen columns where they are weaker than contiguous beams.

(v) Address the issue of the "one-way" structural system described in Section 3.2.2.

(vi) Because of the impracticability of protecting the property from storm surge, the facility should cease to be the only (or main) referral hospital for Belize (*ie* a new one should be constructed) and the present building reallocated for less-critical functions.

Since the buildings will continue in use, and since their occupancy population will likely be large, all of the recommendations made for the KHMH in this document should still be implemented even if the facility is downgraded as recommended above.

4.5 Final Thoughts (by Another)

From:
An Unexpected Light (*ex* pages 266 & 267 from a book about the author's travels in Afghanistan)
by Jason Elliot
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I met the English-speaking dervish Yusuf the following day. He invited me to visit the hospital he had designed and had built in the north of the city[15]. A team of workmen was putting the finishing touches to the construction as we arrived, and Yusuf conferred with them in turn as we walked along freshly laid concrete pathways.

It was unlike any other structure I had seen in Afghanistan. The main building consisted of a series of interlocking geodesic domes built from panels of pre-stressed concrete. They had been painted white and resembled a cluster of small observatories or a miniature version of the observation tower at the Arizona Biosphere.

When I expressed surprise at the design Yusuf explained that with his architectural team he had wrestled over the problems of its construction for a long time, being reluctant to build the usual concrete boxes, which although less complicated to construct were difficult to heat in winter and grew too hot in the summer. They had taken their inspiration from the traditional domed structures of the villages around Tashgurgan and expressed them in modern materials.

'We wanted to do something that was not only useful but beautiful,' he said. A workman was preparing soil in flowerbeds that curved between the walkways. 'There is a *hadith*: everything should be in balance.'

Inside the rooms were light; the high domed ceilings were a refreshing and unaccustomed shape. Yusuf expressed the hope that the design would provide a better atmosphere for sick people to heal in; it was well understood, he said, that the shape and colour of rooms could influence the healing process. There was an appropriate design for a hospital as much as for an office or a home; the design had to take account of the building's function, as well as the community it served. He was deeply concerned with the problems of community and the potentially integrative role of architecture; all too often the social aspect of buildings was overlooked.

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We sat together and drank tea in one of the rooms. I asked him how he had come to be involved with the *Mir* and Sufism. His father had been a Sufi; but as a young man he had no time for it, only later, when the communists had sent him to prison, had he taken an interest. I asked how long he had been in prison.

'Seven years,' he said, with a faint smile.

After his release he had escaped to Pakistan, been reunited with his wife, and begun his studies as an architect. I wanted to ask him what it was that had drawn him to the *tariqat*, and what form his instruction had taken; it puzzled me to reconcile this industrious and forward-looking man with conventional notions of mysticism. He seemed to anticipate my question.

'You can look at it like this,' he said, opened his notebook, and wrote, with a calligraphic flourish, a couplet of rhyming, lines from the Indian Sufi poet, Bedīl:

Greed for a hundred worldly glories is beggary;
When you reach contentment, poverty is wealth.

Then he tapped the pen against the first word: *Hars.* It meant greed, or attachment.

'That is the problem,' he said gently. 'That is the problem that Sufism addresses.'