GEOG 455 Exercise Five
SHELTER DESIGN
20 points

Name:_____
Student#:_____

Background

The design of shelter within any climatic regime is an exercise that is becoming a joint venture for the climatologist and the architect. A check of the advertisements in the back issues of the Bulletin of the American Meteorological Society over recent years shows a substantial increase in the number of atmospheric scientists now wishing to assist in the home/office design process. Many architectural firms have detailed climatological profiles prepared as the planning process proceeds. Familiarity with these profile methods and the design process itself should be part of an applied climatologist's skills.

The following material is typical of the background information that is used in the design process. The first pages, entitled Narrative Climatological Summary for Middle City, is the minimum necessary for you and the architect in the way of climatic data. The data and summary are representative of the macroclimate, which most strongly influences the basic design of any structure. The last page of the first section shows the lot on which a structure is to be constructed. Mesoscale and microscale features of the environment become important at this scale, although they are the most difficult to work into the design process. The second section, entitled "The Mahoney Tables", presents one of several ways in which climatic data can be summarized so that particular design elements needed in a particular climatic regime are emphasized. After you complete the tables (1-5), you can begin to address the specifications listed in the section entitled Summary of Recommendations for the Sketch Design Stage. The creation of various design alternatives creates an internal microclimate that should have as its goal maximizing human comfort.

Assignment

Your assignment is to work through the various sections, calculating all information necessary for the Mahoney Tables. You should also include a rough sketch of your proposed dwelling for the lot (Figure 1), and a short statement on your rationale for each of the necessary specifications in the Sketch Design Stage section of the handout.

NARRATIVE CLIMATOLOGICAL SUMMARY FOR MIDDLE CITY

Middle City is located in a plateau area with a general elevation near 990 meters (3250 feet). The Middle City Plateau is an essentially level area with numerous small temporary Lakes, small stream valleys and low hummocks. During the rainy months depressions gradually collect runoff water and form small lakes and ponds. The small stream valleys gradually drain into the major rivers of the area, but these stream valleys throughout most of the year carry only a very light flow. There are no appreciable terrain features affecting wind flow across the plateau. However, east and southeast winds do undergo considerable change as they are deflected upward over an escarpment which makes the eastern boundary of the Middle City Plateau.

The climate of the area is semiarid, transitional between desert conditions on the west and humid climates to the east of southeast. The normal annual precipitation is 468 mm. (18.41 inches). Maximum precipitation usually occurs during May, June, and July, when warm, moist, tropical air is carried inland from the Gulf of Mexico. This air mass produces moderate to heavy afternoon and evening convective thunderstorms, sometimes with hail.

Snow occasionally occurs during the winter months, but is generally light and remains on the ground only a short time. Precipitation in the area is characterized by its erratic nature, varying during the period of record from as much as 1030.0 mm. (40.55 inches) to only 221.7 mm. (8.73 inches) annually, and from as much as 353.8 mm. (13.93 inches) to none in one month.

The normal annual temperature is 15.4°C (59.7°F). The warmest months are June, July, and August, with a normal daily maximum in July of 33.3°C (92°F). The record maximum temperature of l.7°C (107°F) occurred in June 1957 and July 1958.

The coldest months are December and January with a normal daily minimum temperature in January of -4.0°C (24.8°F) and a monthly mean of 4.0°C (39.1°F). The record minimum temperature of -26.7°C (-16°F) occurred in January 1963.

Maximum winds are usually associated with intense thunderstorms and although of short duration are on occasion very damaging. Winds in excess of 40 kilometers per hour (25 mph.) Occasionally occur for periods of 12 hours or longer. These prolonged winds are generally associated with late winter and springtime low pressure centers and usually blow from the south or southwest. Dust storms are a variable factor in the climate and are dependent upon the current and preceding year's precipitation patterns and the agricultural practices of the local and upstream areas. Most extensive dust storms are noted with southwesterly, westerly, or northwesterly winds. The coldest winds tend to come from the north and northwest with the passage of winter fronts.

The summer heat is generally not considered oppressive. The moderating factors are daytime wind and rather dry air. Nighttime temperatures are generally considered pleasant with most summer minimums in the high teens Celsius (sixties Fahrenheit). The climate of the region is generally pleasant. Most periods of disagreeable weather are of only one or two days' duration and usually occur in the late winter or spring months.

VEGETATION OF THE MIDDLE CITY AREA

The Middle City area is located in a natural grassland. Although long periods of drought (see Middle City climate data) inhibit the growth of trees, grasses can survive well. The grass may die to the ground during prolonged dry spells, but the roots persist and send up new shoots after a rain. Areas with heavy soils, most of which are located 30 to 40 miles or more north of Middle City, have natural growth of buffalo grass, with some grama grass, which becomes one or two feet tall in seasons of normal precipitation. Grama grass is rather abundant in the southern part of the area around Middle City, where the soil is sandy loam.

Light, sandy soils in the area support a bunch grass vegetation, which consists chiefly of bluestem or sedge grass, with some needle grass. Sin oak covers this loose land at some places, and the southern portion of the area has scattered growth of catclaw, mesquite, and other shrubs. The only trees found in the area are scattered cottonwoods and oaks along stream courses, most of which were removed by early settlers for building or fire wood.

SELECTED CLIMATE DATA FOR MIDDLE CITY

Mean Monthly Temperature (°C)

	J	F	M	A	M	J	J	A	S	O	N	D
Max	11.9	13.9	17.7	23.8	28.1	32.0	33.6	32.9	28.8	23.7	17.3	12.9
Min	-4.0	-2.0	1.1	7.3	12.5	17.6	19.4	18.6	14.6	8.5	1.3	-2.6
Range	15.9	15.9	16.6	16.5	15.6	14.4	14.2	14.3	14.2	15.2	16.0	14.3

Monthly Mean Relative Humidity

Max	72	71	67	69	75	76	76	78	81	78	74	71
Min	46	40	34	32	36	36	40	41	46	45	47	46
Mean	59	56	51	51	56	56	58	60	64	62	61	59

Mean Precipitation in mm.

14	13	23	27	81	71	57	47	56	52	12	15

Mean annual precipitation - 467.6 mm.

WIND DIRECTION AND FREQUENCY FOR MIDDLE CITY*

Compass Bearing	Month J	F	M	A	M	J	J	A	S	O	N	D
N	9.8	10.9	3.4	1.7	1.6	1.5	2.3	2.3	4.6	2.8	8.4	8.9
NNE	3.0	5.4	3.4	2.4	2.7	2.8	1.6	3.0	3.6	1.2	4.9	8.9
NE	2.4	4.6	3.5	2.4	4.7	1.3	1.1	4.7	2.6	0.9	1.4	5.2
ENE	1.9	4.2	4.8	4.9	6.3	3.8	1.9	6.6	4.6	0.9	2.6	4.8
E	0.4	4.9	5.8	5.8	5.5	3.8	2.7	7.9	7.9	2.7	3.3	3.0
ESE	2.0	5.2	10.9	7.9	15.9	21.8	9.4	12.6	15.4	7.8	5.4	2.3
SE	5.0	4.2	6.7	7.2	11.4	21.8	17.3	14.9	16.9	19.1	6.9	2.7
SSE	5.5	2.7	11.3	8.5	14.7	20.7	31.0	16.0	12.9	20.8	10.7	4.2
S	5.4	3.1	5.0	5.7	11.0	6.9	14.0	7.5	6.8	10.3	11.7	12.2
SSW	7.0	6.7	4.8	9.0	5.4	3.9	6.7	6.9	2.9	5.9	5.7	6.3
SW	6.2	9.1	8.7	11.6	5.1	2.4	2.8	2.4	1.9	5.2	6.5	7.4
WSW	16.1	8.0	11.0	13.3	5.0	1.8	1.6	1.2	1.9	5.4	7.4	7.4
W	13.2	14.7	6.6	9.4	4.4	2.1	1.1	2.3	3.2	4.6	9.3	6.7
WNW	5.4	5.4	4.4	4.3	1.9	1.3	0.7	0.3	3.1	3.8	4.4	9.7
NW	2.0	3.7	1.9	2.8	0.9	0.8	1.2	1.2	1.0	1.5	2.5	3.1
NNW	13.0	5.7	6.6	2.2	1.9	1.9	0.9	2.8	2.5	2.3	6.0	3.9
calm	1.7	1.6	1.2	0.8	1.6	1.3	3.6	7.4	8.1	4.7	2.8	3.4

*Values are for percent of observations.

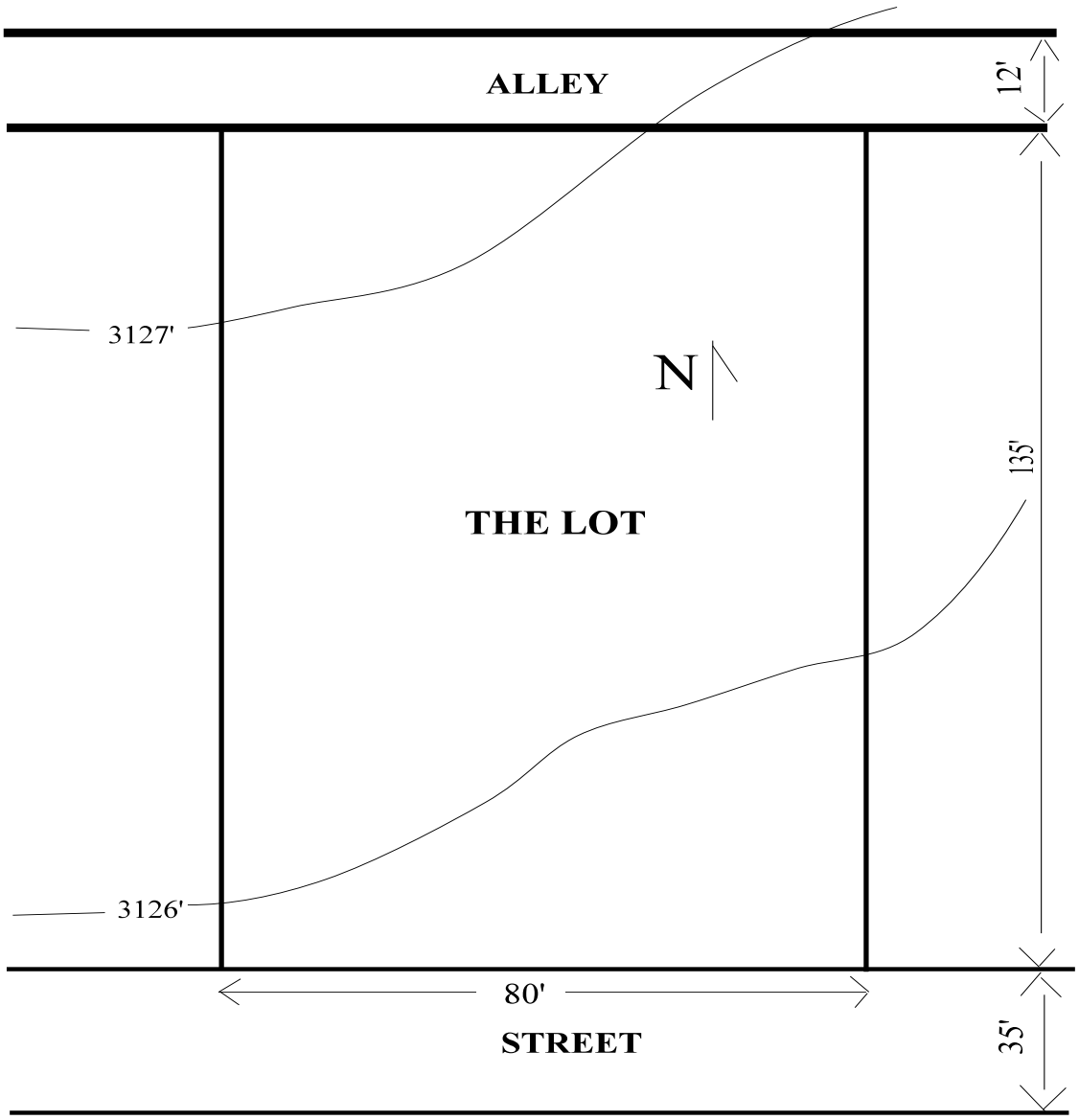

FIGURE 1

THE MAHONEY TABLES[1]

The Mahoney tables provide a guide to design in relation to climate using readily available climatic data. By following a step by step procedure the designer is led from the climatic information to specifications for optimal conditions of layout, orientation, shape and structure needed at the sketch design stage.

The analysis requires the use of five tables. To retain the orderly nature of the original work, the tables are numbered 1 through 5. You should work on the problem *following the numerical sequence of tables*.

Instructions for Table 1: Air Temperature

(a) Record in Table 1 the monthly mean maxima and minima of temperature;

(b) Enter to the right of the air temperature figures the highest of the monthly Mean maxima and the lowest of the monthly mean minima;

(c) Find the annual mean temperature (AMT) by averaging the monthly mean maxima and minima, adding the averages together, and dividing by two. Enter this value in the far right column under the letters AMT.

(d) Enter the monthly mean range for each month from the climate data set onto The appropriate row of Table 1.

(e) Find the annual mean range (AMR) of temperatures by deducting the lowest of the monthly mean minima from the highest of the monthly mean maxima and entering The result in the box marked AMR.

Instructions for Table 2: Humidity, Rain and Wind

(a) Record in Table 2 the monthly mean maxima and minima of relative humidity (RH) for each month (early morning and early afternoon readings);

(b) Record below these maxima and minima the average relative humidity for each month;

[1]From United Nations, Department of Economic and Social Affairs, Design of Low-Cost Housing and Community Facilities, Vol. 1, Climate and House Design, United Nations, New York, 1971.

(c) Note below this the "humidity group" (HG) for each month, using the following code:

Average RH	Humidity Group
Below 30 percent	1
30-50 percent	2
50-70 percent	3
Above 70 percent	4

(d) Record in Table 2 the monthly rainfall figures in the millimeters and add them Up to find the annual rainfall (already calculated for Middle City);

(e) Record for each month the direction of the prevailing wind and of the secondary wind selected from first and second peaks of frequency figures. These data will not be applied in your calculations, but they will be useful in determining orientations of buildings for proper ventilation or protection from cool winter breezes.

Instructions for Table 3: Diagnosis of Climatic Stress

(a) Record on the line labeled Humidity Groups the correct number for each month as calculated on Table 2.

(b) On the table labeled Comfort Limits below identify the proper AMT category as calculated in Table 1.

COMFORT LIMITS

	AMT over 20°C		AMT 15-20°C		AMT under 15°C		
Average RH (percentage)	HG	Day	Night	Day	Night	Day	Night	HG
0-30	1	26-34*	17-25	23-32	14-23	21-30	12-21	1
30-50	2	25-31	17-24	22-30	14-22	20-27	12-20	2
50-70	3	23-29	17-23	21-28	14-21	19-26	12-19	3
70-100	4	22-27	17-21	20-25	14-20	18-24	12-18	4

*temperature ranges for comfort limits in °C.

(c) Enter the monthly mean maximum and minimum temperatures for each month from Table 1 on the appropriate lines of Table 3.

(d) From the table above calculate the comfort limits for each month, day and night, by finding the appropriate column for the AMT and reading across to the intersection with the humidity group for the month. The values in the columns are the ranges of comfortable temperatures given humidity and AMT. Enter the maximum and minimum comfort limits in the appropriate lines of Table 3. Note that there are separate ranges of comfortable temperature for Daytime and nighttime.

(e) Compare the monthly mean maxima with the day comfort limits and compare the Monthly mean minima with the night comfort limits and enter the following symbols into the last two lines of Table 3 under the rating of thermal stress (day and night):

Above comfort limits	H (hot)
Within comfort limits	- (comfort)
Below comfort limits	C (cold)

Instructions for Table 4: Indicators

Certain groups of symptoms of climatic stress indicate the remedial action the designer can take. We refer to them as indicators. They tend to be associated with humid or arid conditions. One indicator by itself does not automatically lead to a solution. Recommendations can be framed only after adding the indicators for a whole year and completing Table 4.

Humid indicators. H1 indicates that air movement is required. It applies when high temperature (day thermal stress = H) is combined with high humidity (HG = 4) or when the high temperature (day thermal stress = H) is combined with moderate humidity (HG = 2 or 3 and a small diurnal (daily) range of mean max. and min. temperature (Dr less than 10°C);

H2 indicates that air movement is desirable. It applies when temperatures within the comfort limits are combined with high humidity (HG = 4);

H3 indicates that precaution against rain penetration are needed. Problems may arise with low precipitation figures, but will be inevitable when rainfall exceeds 200 mm per month.

Arid indicators A1 indicates the need for thermal storage. It applies when a large diurnal range (10°C or more) coincides with moderate or low humidity (HG = 1,2, or 3);

A2 indicates that desirability of outdoor sleeping space. It is needed when the night temperature is high (night thermal stress =H) and the humidity is low (HG = 1 or 2). It may be needed also when nights are comfortable outdoors but hot indoors as a result of heavy thermal

storage (i.e., day = H, humidity group = 1 or 2 and when the diurnal range is above 10°C);

A3 indicates winter or cool-season problems. These occur when the day temperature falls below the comfort limits (day thermal stress = C);

Check in table 4 the months when each of these indicators applies and add the total number of months for each indicator.

Further Recommendations

After completing Table 4, the designer is ready to lay down specifications. His/her recommendations depend on the number of months during which one or several of the indicators A and H apply.

Table 5 helps to formulate recommendations for those features of the building that must be decided during the sketch design stage.

The recommendations are grouped under the following eight subjects:

1. Layout
2. Openings
3. Spacing
4. Walls
5. Air movement
6. Roofs
7. Outdoor sleeping
8. Rain protection

Instructions for Completing Table 5

(a) Transfer the indicator totals from Table 4 to Table 5 (you may do this by circling in pencil the appropriate values on Table 5).

(b) Deal with the eight subjects one by one, i.e., layout, spacing, air movement, etc.

(c) Examine the indicator lines for each subject to find the appropriate recommendation;

(d) There can be only one recommendation per subject. It is the first you come across while scanning from left to right;

(e) A further alternative exists in a few cases, namely, recommendations 1 or 2, 6 or 7, and 7 or 8. In these cases, the choice is made by proceeding with the scanning of the indicator columns to the right and deciding according to the range of months given in the table.

SUMMARY OF RECOMMENDATIONS FOR THE SKETCH DESIGN STAGE

Layout

1. Buildings should be oriented on an east-west axis with the long elevations facing north and south to reduce exposure to the sun. If thermal storage is required for up to ten months or if thermal storage is required for eleven or twelve months including more than four winter months (A3). The buildings may be turned slightly to catch the prevailing breeze (see recommendation No. 6 and the wind directions for the high humidity months in Table 2) or to allow limited solar heating during the cold season (A3).

2. Buildings should be planned around small courtyards, if thermal storage (A1) is required for eleven or twelve months and the cold season (A3) is less than five months.

Spacing

3. Buildings should be well spaced to allow for breeze penetration, if air movement (H1) is essential for eleven or twelve months. As a rough guide, the space between long parallel rows of buildings should be five times the height of the buildings or more.

4. If air movement (H1) is needed between two and ten months of the year spacing for breeze penetration is still needed, but buildings and planting should also be planned to give protection against dusty hot or cold winds (see Table 3 for conditions and Table 2 for wind directions).

5. Compact planning is essential if air movement (H1) is needed for not more than two months.

Air Movement

6. Rooms should be single banked with windows in the north and south wall if air movement (H1) is essential for more than two months. Single banking is desirable if air movement is needed for one or two months and thermal storage (A1) for zero to five months.

7. Rooms may be double banked if air movement (H3) is needed for not more than one or two months. If there are months when air movement is not essential but desirable (H2), the plan should allow temporary cross-ventilation (e.g., it could be double banked with large interconnecting doors). If the prevailing wind is unreliable or if site limitations restrict planning for air movement, ceiling fans should be considered. This must be done at the sketch design stage, because it implies minimum room heights of not less than 2.75 meters.

8. Rooms should be double-banked if air movement (H1) is never required to achieve comfort or is required to maintain comfort (H2) for one month or less.

Openings in Walls

9. Openings should be large (between 40-80 percent of the north and south walls) if thermal storage (A1) is required for less than two months and there is no cold season (A3). Large openings need not be fully glazed, but should be protected from sun, sky glare, and rain, preferably by horizontal overhangs.

10. Small openings (less than 25 percent) should be used if thermal storage (A1) is needed for eleven or twelve months and the cold season (A3) is less than two months.

11. In all other conditions, medium sized openings should be used (from 25 percent to 40 percent of the area of the north and south walls). Openings in the east walls are desirable only if there is a long cold season (A3). Openings in west walls are desirable to cold and temperate climates, but must be avoided in the tropics.

Walls

12. External walls should be light with a small heat capacity if thermal storage (Al) is needed for less than three months. Internal walls should be heavy if the annual range is high (over 20°C).

13. External and internal walls should be heavy with high heat capacity if thermal storage (A1) is needed for three to twelve months.

Roofs

14. A light but a well-insulated roof should be used if thermal storage (A1) is needed for less than six months.

15. A heavy roof should be used if thermal storage (A1) is needed for six to twelve months.

NOTE: Glazed skylights or roof lights should never be used in the tropics.

Outdoor sleeping

16. Space for outdoor sleeping should be provided if indicator A2 applies for more than one month of the year. Sleeping spaces on roofs or balconies or in patios should be exposed to the coldest part of the night sky to permit heat loss by out-going radiation.

Rain protection

17. Special protective measures are needed if rain is frequent and heavy (H3), e.g., deep verandahs, wide overhangs and covered passages.

Recapitulation

The climatic analysis of the sketch design stage ends with the completion of Table 5 and the recommendations which follow from it.

After completing Tables 1 to 5 and noting the recommendations, the designer should pause for a few moments and reflect on the process followed. It is important that he/she should be conscious of the logic of this process and not consider it as either arbitrary or mysterious.

What has been done is this: he/she has recorded the dominant features of this climate one by one, noting for each the period during which it is operative. Certain combinations of climatic features indicate that forms of layout, construction, fabric or surface treatments are appropriate.

Different seasons bring different combinations of climatic features. In many cases, the designer can find answers that are appropriate for more than one season. In others, he/she has to decide according to the season that lasts longest. If one does this they must be aware that there will be periods when the over-all concept of this building will be less than perfect. This does not invalidate the decisions arrived at through the use of the Mahoney tables. It means merely that climatic design must not end with the completion of the sketch design stage.

TABLE 1

AIR TEMPERATURE (°C)

	J	F	M	A	M	J	J	A	S	O	N	D	Highest	AMT
Monthly mean max.														
Monthly mean min.														
Monthly mean range													Lowest	AMR

TABLE 2

HUMIDITY, RAIN AND WIND

RH (percentage)	J	F	M	A	M	J	J	A	S	O	N	D	
Monthly mean max. a.m.													
Monthly mean min p.m.													
Average													
Humidity group													Total
Rainfall (mm)													
Wind: P Prevailing													
Secondary													

TABLE 3
DIAGNOSIS

	J	F	M	A	M	J	J	A	S	O	N	D
Humidity group												
Temperature (°C)	----------											
Monthly mean max.												
Day comfort: Max. (From table on page 8) Min.												
Monthly mean min.												
Night comfort: Max. (From table on page 8) Min.												
Thermal stress	----------											
Day												
Night												

TABLE 4

INDICATORS

	J	F	M	A	M	J	J	A	S	O	N	D	Totals
Humid -------			----------										
H1 Air movement (req)													
H2 Air movement (des.)													
H3 Rain protection													
Arid	----------												
A1 Thermal storage													
A2 Outdoor sleeping													
A3 Cold-season problems													

TABLE 5: SKETCH DESIGN RECOMMENDATIONS

Indicator totals from Table 4						Recommendations
Humid			Arid			
H1	H2	H3	A1	A2	A3	
						I. Layout
			0-10			1. Buildings oriented on E-W axis to reduce Exposure to sun
					5-12	
			11or12		0-4	2. Compact courtyard planning
						II. Spacing
11 or 12						3. Open spacing for breeze penetration
2-10						4. As 3, but protect from cold/hot wind
0 or 1						5. Compact planning
						III. Air movement
3-12						6. Rooms single banked. Permanent provision for air movement
			0-5			
1 or 2			6-12			7. Double-banked rooms with temporary provision for air movement
0	2-12					
	0 or 1					8. No air movement required
						IV. Openings
			0-1		0	9. Large openings, 40-80% of N & S walls
			11or12		0 or 1	10. Very small openings, 10-20 %
	Any other conditions					11. Medium openings, 20-40%
						V. Walls
			0-2			12. Light walls, short time lag
			3-12			13. Heavy internal and external walls
						VI. Roofs
			0-5			14. Light insulated roofs
			6-12			15. Heavy roofs; over 8 hours' time lag
						VII. Outdoor sleeping
				2-12		16. Space for outdoor sleeping required
						VIII. Rain protection
	3-12					17. Protection from heavy rain needed