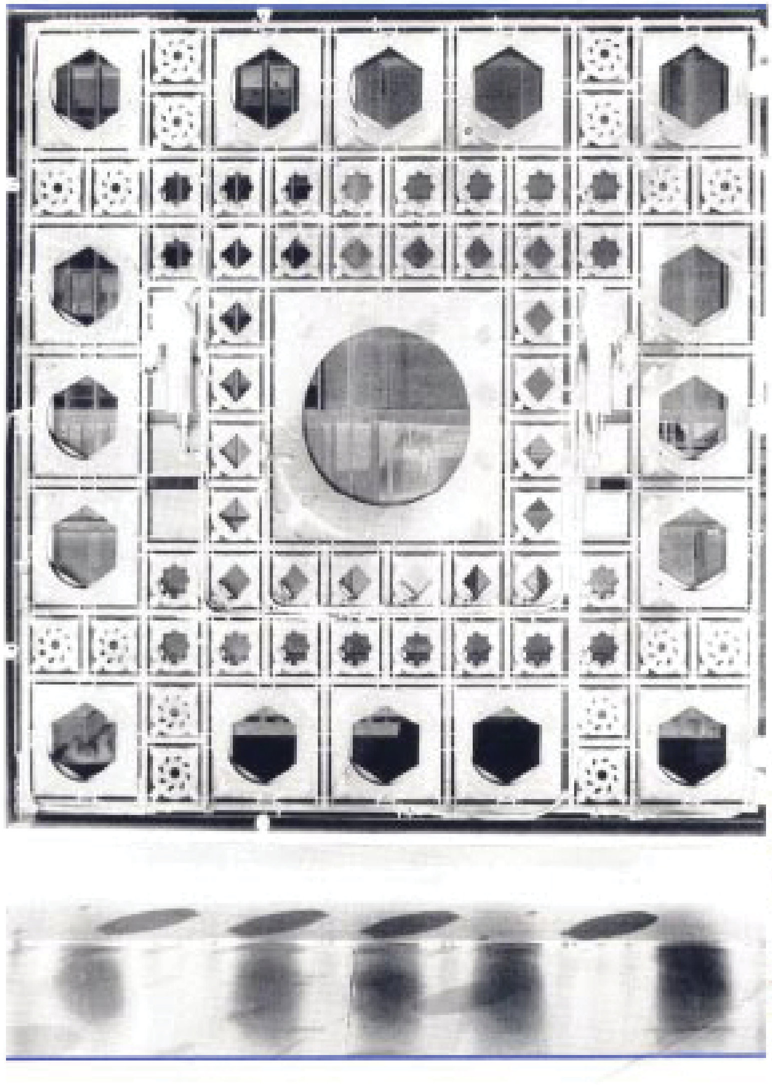
INSIDE Out

Second Edition



DESIGN PROCEDURES FOR PASSIVE ENVIRONMENTAL TECHNOLOGIES

A1 - B1 Thermal

G. Z. Brown

Bruce Haglund

Joel Loveland

John S. Reynolds

M. Susan Ubbelohde

Illustrations by Amy Dowty

PRECEDENTS OF THERMAL RESPONSE

INTRODUCTION

Goal

Assessing technologies in well understood ethnological and climatic contexts can yield principles of design technology that can be generalized and applied to similar contexts. Thus, through the study of less energy-intensive building technologies in either traditional or industrialized cultures, you will gain insights for solving energy-related architectural problems.

> *Modern history has centered its attention on anonymous architecture . . . vernacular architecture has become a subject of intense research. What is the cause of this interest? Is it simply social or psychological curiosity, a decadent boredom with official architecture, or a romantic preference for the primitive or exotic?*
>
> *—Bruno Zevi*

Discussion

Bruno Zevi has posed simplistic questions (right) that challenge the heart and reason for the study of architectural precedents and their applications in the design of buildings today. Does reference to design precedent reflect a "decadent boredom" or merely quixotic stylistic preference? Such a black-and-white assessment grossly over-simplifies the reasons for incorporating architectural precedents. Rather, the questions to ask are: what should we study, why should we study it, and what can we learn from it that will improve our design skills?

The study of architectural precedents should focus on the processes of cultural and physical geographic differentiation through which people create and inhabit various systems of settlement. The study should not be of buildings alone, but of the values, activities, traditions, and physical constraints that influenced the design and the construction methods used in response to climate and comfort (Rapoport 1990).

If we only imitate architectural precedents, the resulting buildings can be out of context and, at the worst, decadent and romantic. Architectural precedents must be studied both as processes and final products of contextual decision-making. This investigation can lead to a clearer understanding of the vernacular form from which design principles can be delineated and later applied.

It is the application of these principles in their appropriate contexts that gives the study of architectural precedents importance. Rather than looking at decisions based on high finance or influenced by the vagaries of the style of the moment, focus on architectural decisions based on intuitive, analytical assessments of the problems faced in contemporary design. Or study examples of the more slowly evolving, tested craft of owner-built traditional architecture (Hubka 1984). These principles are important lessons for not only the designer, but anyone attempting to understand the richness of cultural and physical adaptation in architecture as a whole.

> *In developing theories, generalization is of great importance . . . and can only be made if based on the broadest possible evidence. . . . this evidence must include the full range of what has been built: preliterate, vernacular, popular, and spontaneous (squatter) environments as well as the more familiar high-style settings; . . . the relationships among different environments; all cultures, so that the evidence must be cross-cultural; and the full time span of built environments . . .*
>
> *—Amos Rapoport*

In this section you will:

1. Investigate precedents of climatic response in buildings.
2. Generalize principles of climatic response in climatic and cultural settings.

PRECEDENTS OF THERMAL RESPONSE

A1

ARCHITECTURE, CLIMATE, AND PEOPLE—VERNACULAR PRECEDENTS

A1.1

Procedure

Assess how a particular culture's vernacular architecture, the indigenous and traditional architecture of the region, balances culture and climate. Observe how cultural, technical, and economic forces were integrated with those of climate and thermal comfort to influence building form.

> *. . . vernacular [architecture] could best be studied from a specific point of view, raising specific questions about topics or themes, rather than chronologically, the way traditional architectural history is studied.*
>
> *—Amos Rapoport*

Choose a vernacular building or cluster of buildings in a climate zone similar to your site's. Consider the climate of the locale and the living patterns of its residents. Look for evidence of how such patterns are affected by climate and thermal comfort. Analyze the heating and cooling strategies used in terms of their cultural and physical contexts.

Document your choice as follows:

1. Identify the location of your vernacular building.
2. Describe the climatic characteristics of its locale.
3. Draw a building response diagram to illustrate how seasonal or diurnal changes in climate affect the living patterns.
4. Document your findings using vignettes, photocopies, photographs, etc. with concise and clearly written annotations. Include any uncertainties, questions, or ambiguities that would require additional research. Your analysis should be no longer than two 8½" x 11" pages.

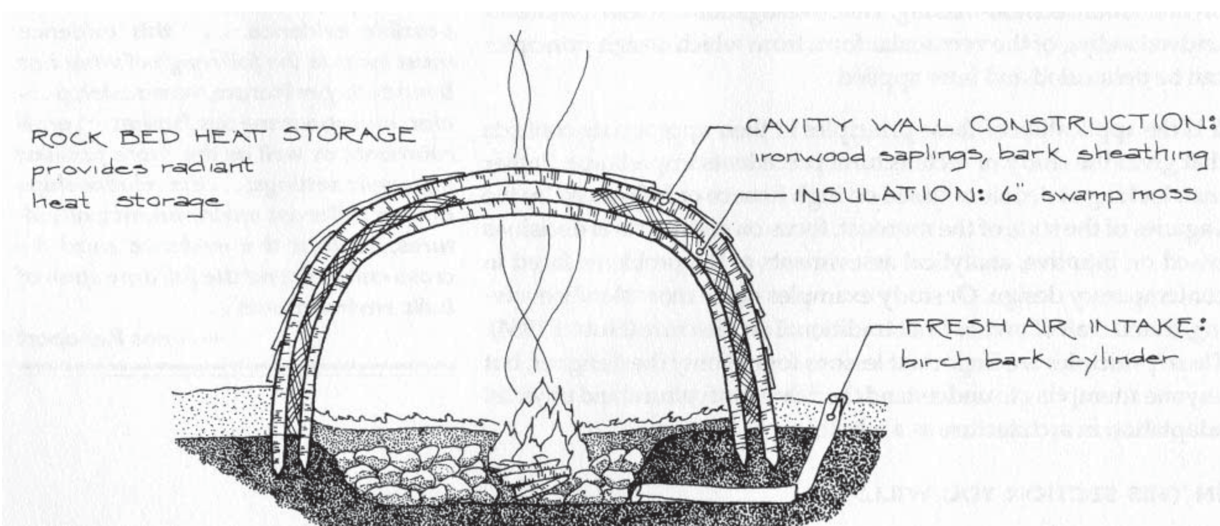


Figure A1.1.1 Modern Great Lakes Wigwam. Adapted from *Native American Architecture* by Peter Nabokov and Robert Easton, 73 (after E. St. Germaine, n.d.). Copyright © 1989 by Peter Nabokov and Robert Easton. By permission of Oxford University Press, Inc.

COOLING PRECEDENTS

Cooling Design Strategies

Site-Scale Strategies

- Choose cool places for summer spaces.
- Use the wind for cooling.
- Use heat sinks for cooling. (A heat sink is any cool mass that is available for the absorption of excess heat, including water bodies, the ground, and massive building materials.)

Cluster-Scale Strategies

- Arrange the buildings to shade each other and their outdoor spaces.
- Preserve each building's access to cooling breezes during overheated periods.
- Use arcaded courtyards for shading and night-sky radiant cooling.

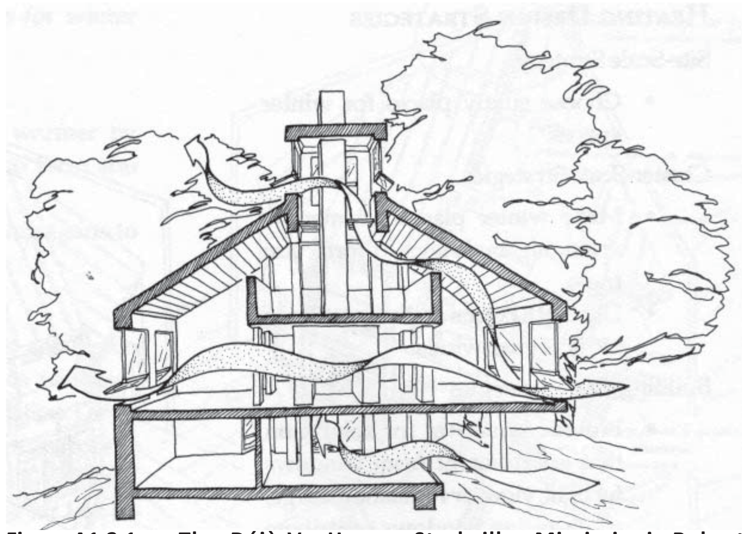


Figure A1.2.1 The Déjà-Vu House. Starkville, Mississippi, Robert Ford (architect), 1983.

Building-Scale Strategies

- Orient buildings toward cooling breezes.
- Couple buildings to heat sinks.

Component-Scale Strategies

- Provide openings for ventilation that can be separate from those used for view, sunlight, or daylight.
- Use water features for evaporative cooling.

Procedure

Choose an existing building or site that has: (1) a building program, summer climate, or both that is similar to your assigned building program or climate and (2) a clear, conceptual approach that incorporates some of the design strategies above.

Document your choice as follows:

1. Identify the location, program, architect (if known), and source of your information.
2. Include photocopies or drawings (whichever is quick and easy for you) to illustrate the design.
3. Evaluate the building or site design with a building response diagram and short annotations that explain how this design is organized for cooling.

HEATING PRECEDENTS

Heating Design Strategies

Site-Scale Strategy

- Choose sunny places for winter spaces.

Cluster-Scale Strategies

- Make winter places warmer by arranging buildings to form sun traps.
- Use earth berms and vegetation to block winter winds.

Building-Scale Strategies

- Provide windows for solar gain that are different from windows for light, view, or ventilation. Large, south-facing windows contribute the most to solar gain.
- Use greater wall mass for less severe indoor temperature swings.
- Couple buildings to heat sinks which tend to be warmer than outdoor winter temperatures.
- Minimize north-facing building skin and glazing areas to reduce heat loss.

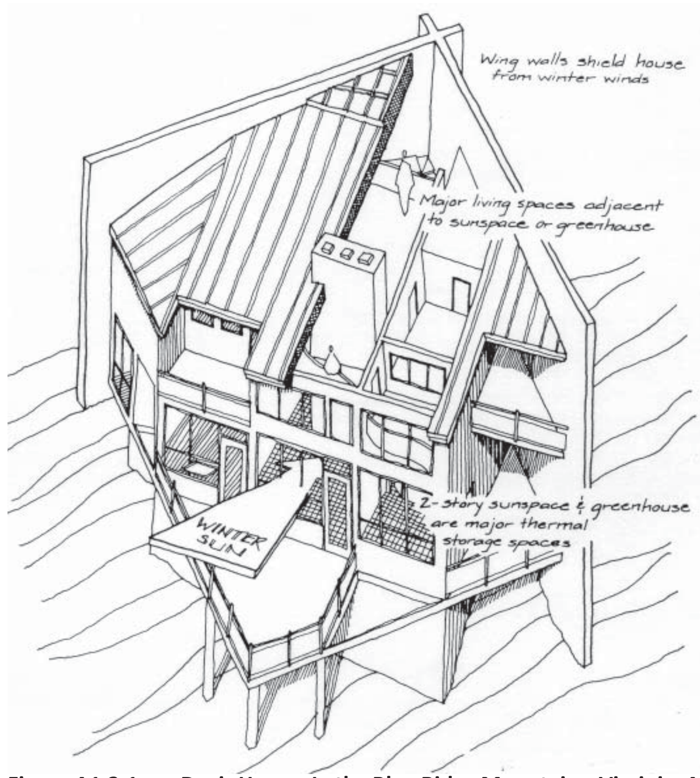


Figure A1.3.1 **Davis House. In the Blue Ridge Mountains, Virginia, A. J. Davis (architect), 1986.**

Procedure

Choose an existing building or site that has: (1) a building program, winter climate, or both that is similar to your assigned building program or climate and (2) a clear, conceptual approach that incorporates some of the design strategies above.

Document your choice as follows:

1. Identify the location, program, architect (if known), and source of your information.
2. Include photocopies or drawings (whichever is quick and easy for you) to illustrate the design.
3. Evaluate the building or site design with a building response diagram and short annotations that explain how this design is organized for heating.

INTRODUCTION

Goal

Determine when your climate is considered comfortable for people and what potential benefits or problems may arise from the sun and wind on your site. Propose a conceptual design responsive to your climate and site.

Discussion

People tend to be comfortable within a fairly narrow range of temperature and relative humidity called the comfort zone. This zone can be extended by providing wind and shade when temperatures are higher, by providing sunshine and blocking wind when temperatures are lower, and by adding moisture when the humidity is low. It is possible, by analyzing your site's seasonal sun and wind patterns, to place the building and outdoor spaces to take advantage of the site's climatic conditions.

In this section you will:

1. Analyze your climatic data to determine which months' conditions fall within the comfort zone and which months' conditions need modifications for comfort.
2. Analyze the wind and sun patterns on your site.
3. Synthesize this information in a schematic design that takes advantage of your site's wind and sun patterns to provide the maximum amount of seasonal comfort.

CLIMATE AND SITE ANALYSIS
BIOCLIMATIC CHART PLOT

Discussion

The bioclimatic chart graphically illustrates the human comfort zone in terms of temperature and relative humidity. It relates comfort information directly to outdoor spaces because it bases the comfort zone on studies of adults at rest, outdoors, and wearing moderate clothing (shirt and trousers). Plotted climate data will indicate when your climate is comfortable and when it may be made comfortable by blocking or admitting the wind or sun. Knowing these potentials allows you to determine when it is possible to comfortably use outdoor spaces on your site and what the design has to accomplish in order to make the best use of the sun and wind.

For more information

Olgyay, *Design with Climate*, Chapter 2, pp.14–23 (discussion of the bioclimatic chart).

Procedure

For your location:

1. Record mean minimum and maximum temperatures and relative humidities (RH) for each month [*From Climate Consultant*].
2. On the bioclimatic chart [Figure B1.1.1] plot two points for each month—High Temperature/Low RH and Low Temperature/High RH. The higher temperature generally coincides with the lower humidity of the day and vice versa. Connect the points with a straight line. Label and/or color code each month's plot.
3. For a worst-case summer condition, find the summer dry-bulb temperature [*MEEB*, Table B.1, pp.1565–1573], and extend your hottest month's line to that temperature on the chart.

   NOTE: The slope of the lines you have just plotted represents a constant moisture content. Extending the line to the summer high temperature reflects the probable humidity at that temperature.

4. Use the results of your bioclimatic chart plot to discuss the natural potential for seasonal comfort, particularly in regard to outdoor spaces (decks, courtyards, etc.). Compare the bioclimatic chart plot with the *Weather Tool* psychrometric chart plot of monthly ranges vs. multiple passive techniques.

Record of Corresponding Average Monthly Temperature (°F) and Relative Humidity (%) [Suggested Format]														
	Tem (HI)	RH (LO)	Tem (LO)	RH (HI)		Tem (HI)	RH (LO)	Tem (LO)	RH (HI)		Tem (HI)	RH (LO)	Tem (LO)	RH (HI)
Jan					May					Sep				
Feb					Jun					Oct				
Mar					Jul					Nov				
Apr					Aug					Dec				

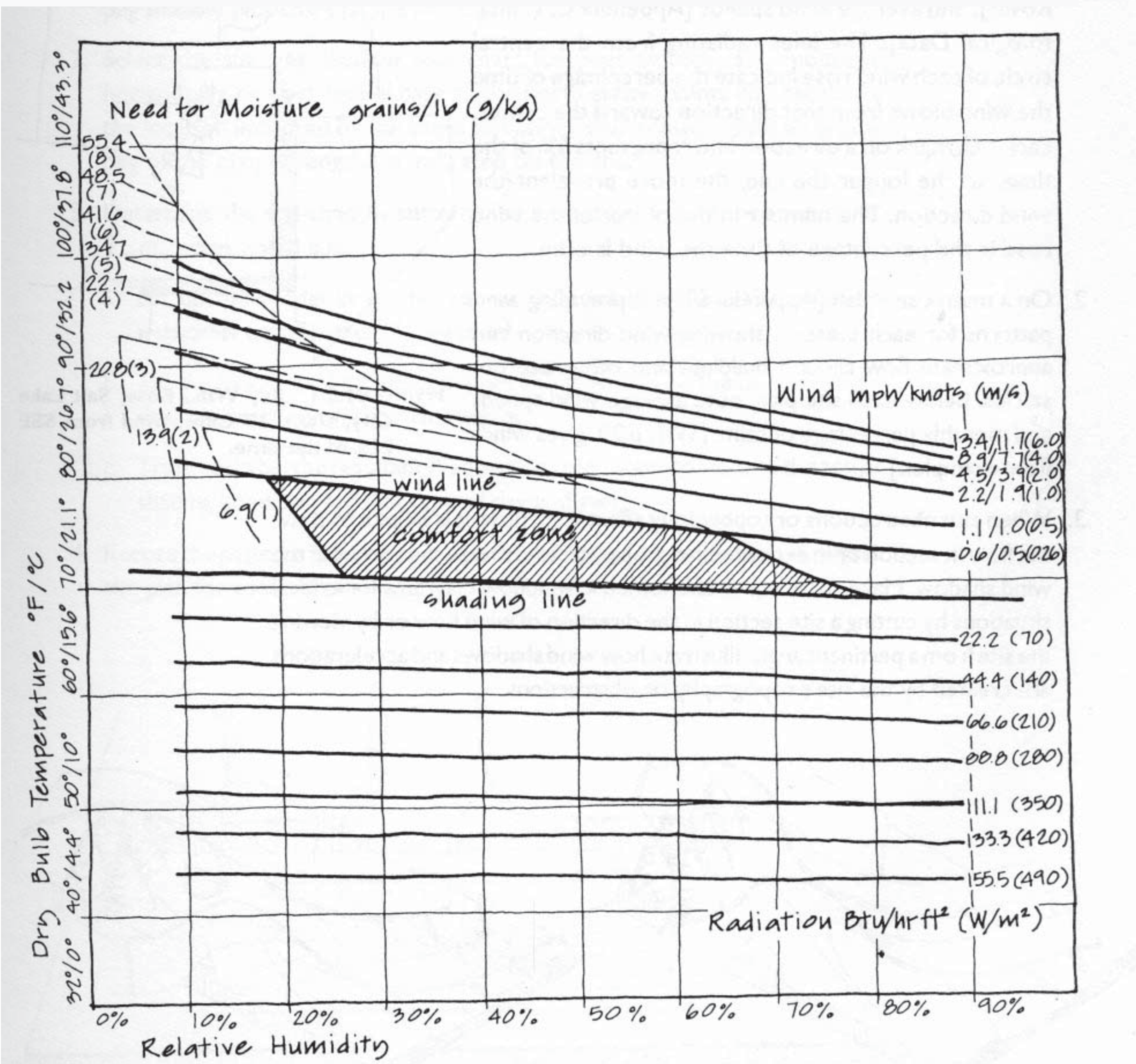


Figure B1.1.1 **Bioclimatic Chart with Design Strategies. Reprinted, by permission, from Brown, *Sun, Wind, and Light*, 35, copyright © 1985, John Wiley & Sons, Inc.**

B1 THERMAL

CLIMATE AND SITE ANALYSIS

B1

SITE WIND FLOWS

B1.2

Discussion

Wind speed and direction often vary seasonally and are affected by site constraints, topography, and vegetation. Additionally, during periods of calm, microclimatic thermal winds caused by valley effects, city effects, or bodies of water may occur. Site windflow mapping of each season can help you orient buildings and outdoor spaces to block wind during cooler months and admit a free flow of wind during warmer months.

Procedure

1. For each season, determine the prevailing wind direction, percentage of calm time, and average wind speeds [Use *Climate Consultant's* Wind Wheel]. The triangles radiating toward the central circle of the wind rose indicate the speed and the gold bars outside the wheel indicate percentage of time the wind blows from that direction toward the center.
2. On a matrix site plan (four small plans on one page), plot prevailing wind patterns for each season, showing wind direction and approximate flow around buildings and other site obstacles. Below each site plan, note average wind speeds and monthly percentage of calm.
3. When site obstructions or topography affect wind flow, it is helpful to draw the flow in section or in axonometric projection to visualize the extent of the wind shadow. Make sectional or axonometric windflow diagrams for critical situations by cutting a site section in the direction of wind flow or by viewing the site from a pertinent angle. Illustrate how wind shadows and accelerations are created by the site's topography or obstructions.

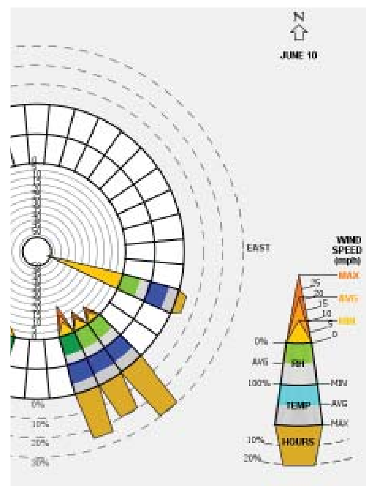


Figure B1.2.1 ***Climate Consultant*** **Wind Wheel**

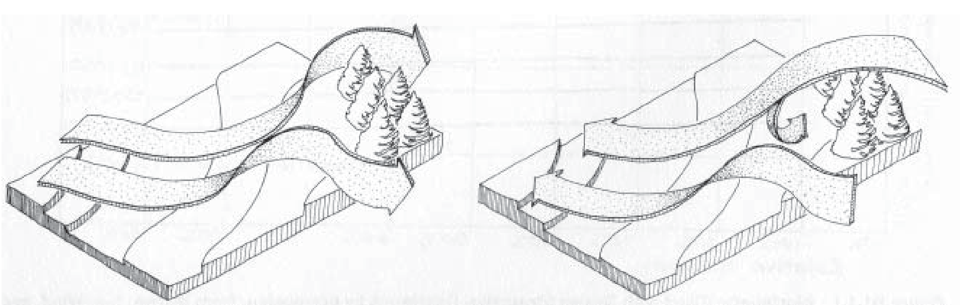


Figure B1.2.2 **Summer and Winter Windflow Diagrams**

SUN PEG SHADOW PLOT

Discussion

This technique shows you how the sun and your site will interact daily and seasonally to form sunny and shady places. This sun peg study requires a site model and a sunny day. Plan to finish your model early so you do not fall victim to extended cloudy weather.

Procedure

1. Use your site context map to make a 1" = 100' scale contour model of your site. Mark off the surface into a 110' x 110' grid and model all vertical obstructions, such as existing buildings, vegetation, and land forms—even if they're beyond your site's borders. Leave about 4" of horizontal space across the southern end of your model for mounting the sun peg shadow plot chart [*MEEB*, App. D.2, pp. 1637–1640 or ***Climate Consultant*** Sun Chart].
2. Select the sun peg shadow plot chart for your latitude, and mount it horizontally on your model base so the north arrow points due north. At the location indicated by the cross just above true south, mount a vertical peg of the proper length (as indicated on the chart).
3. Determine the sun-shadow patterns for a typical month of each season at 9 a.m., noon, and 3 p.m.
   a. Set up the model in the full sun or in a sun simulator. **ORDINARY INDOOR LAMPS DON'T WORK!**
   b. Tilt the model until the tip of the peg's shadow falls on the desired time–date intersection on the shadow plot.
   c. Trace and label the resultant shadows on your model to indicate the actual shading condition for that time of day and year.
4. Record the patterns on a copy of the matrix site plan, one matrix site plan for each season.

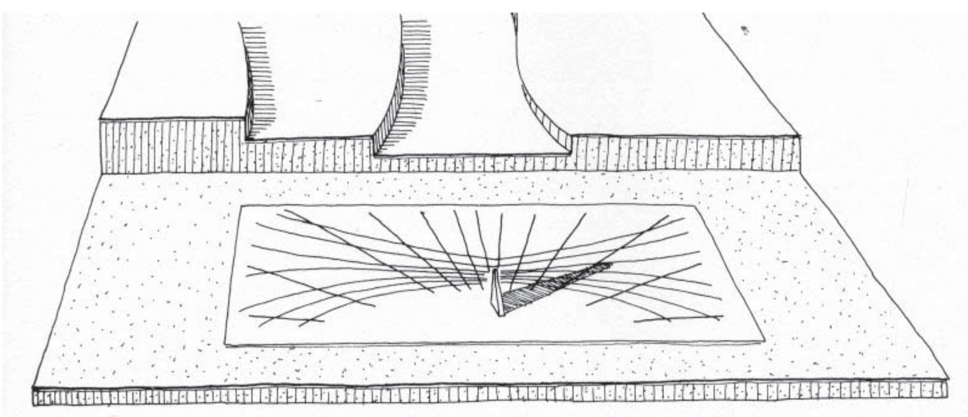


Figure B1.3.1 Sun Peg Shadow Plot Mounted on Model Base

CLIMATE RESPONSE MATRIX

Discussion

With the bioclimatic chart plot you identified requisite climate conditions for comfortable spaces. During hot months block the sun while admitting the wind. During cold months block the wind while admitting the sun. These wind–sun conditions may already exist on your site. You can combine your windflow and sun pattern information with your bioclimatic chart plot information to identify where and when these conditions occur.

Procedure

1. The matrix below represents the four possible combinations of wind and sun access. Color code it to represent the relative warmth of each condition. You will use this rendered matrix as a legend for the site plans to be developed in step 2.

	Sun	Shade
Windward		
Leeward		

2. Determine the wind–sun conditions that naturally occur on the site at 9 a.m., noon, and 3 p.m. in each season.
   a. Synthesize the wind flow and sun shadow pattern plots from B1.2 and B1.3.
   b. Choose a format for your data presentation. Use three pages (9 a.m., noon, and 3 p.m.) with all four seasons on each page, or use four pages (winter, spring, summer, and fall) with all three times of day on each page. Either choice is equally advantageous; they are just different ways of organizing your data.
   c. Using the legend created in step 1, color each 110' x 110' square of each site plan matrix to indicate the naturally occurring wind–sun condition.

CLIMATE RESPONSE MATRIX ANALYSIS

Discussion

The climate response matrix gives you a graphic representation of the naturally occurring climatic conditions on your site. You can look at the twelve matrices that you have made, and make an educated guess as to the most suitable building sites. However, this method is subjective and is done more skillfully with site selection experience. A more analytical alternative is to assign to the squares on your matrices a numerical value based on its viability (after McHarg [1969] 1971).

Procedure

1. Refer to your bioclimatic chart plot [B1.1] to ascertain whether it is necessary to add heat, provide cooling, or do neither to maintain comfort at 9 a.m., noon, and 3 p.m. in each season.
2. For each square of each climate response matrix [B1.4], assign a value representing its climatic suitability for the particular time of day and year it represents. Use the following scale:

   +1 = suitable (has both required wind–sun conditions)

   0 = neutral (has one required condition)

   −1 = unsuitable (has neither required condition).
3. On a separate site plan, record the totals for each square of your matrix. Render the site plan to indicate desirable building locations (positive scores), neutral locations (zero scores), and undesirable locations (negative scores).
4. Examine the rendered site plan. Do you think it's a valid representation of the microclimatic conditions? If not, propose a more effective way of interpreting the climatic data. (For example, if your building has no late afternoon use, the 3 p.m. data should be disregarded or assigned a value less than the 9 a.m. or noon data.)

CLIMATE AND SITE ANALYSIS

SITE CONCEPTS

Discussion

The rendered site plan you developed in B1.5 identifies climatically favorable locations on your site. For each favorable area, propose a conceptual design using very simple, annotated diagrams, the most appropriate level of detail for this stage of the design process. The concept should address the specific thermal needs of your building—what time of day and year outdoor spaces will be used, and what spaces in the building should be exposed to the sun for winter heat or to the wind for summer ventilation.

Procedure

1. Diagram each site design.
2. Annotate the diagrams to explain thermal considerations.
3. Show how you would alter site vegetation and topography to further improve the livability of your site.

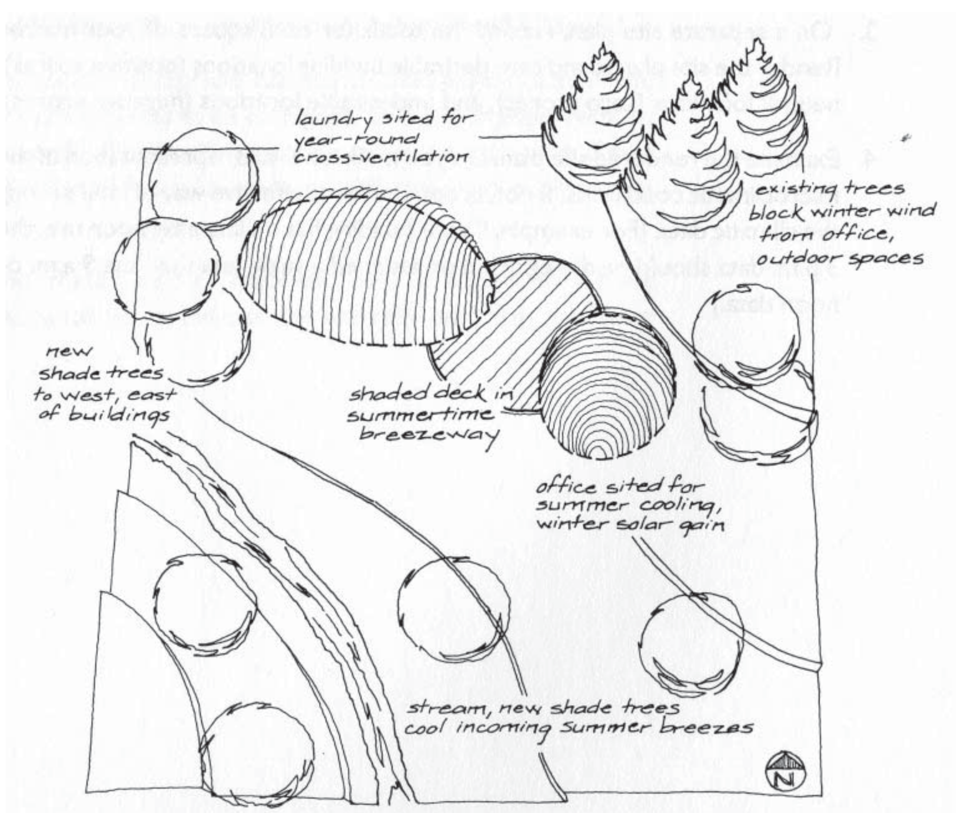


Figure B1.6.1 **Site Design Proposal. Linen supply, Charleston, South Carolina.**