

NATURAL FORCES AND THE CRAFT OF BUILDING:

SITE RECONNAISSANCE

BY

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ABSTRACT

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SITE RECONNAISSANCE

by Vivian Ellen Loftness

Submitted to the Department of Architecture on the 16th of May 1975, in partial fulfillment of the requirements for the degree of Master of Architecture.

Architecture must be consciously and precisely designed to integrate the life of its occupants with the cycles of nature. This thesis is a collection of information on the natural microclimate which exists on the untouched land, and that which could predominate by intervention and design. An understanding of site potentials and limitations involves: first the survey of local climate elements, second the evaluation of each climatic impact in physiological terms, and third the development of a design response for each microclimate condition. Field reconnaissance gives an invaluable overall picture to the designer, enabling him to design with respect for the site. What is proposed here is a method, an index, for reestablishing in built form, a more delicate exchange between man and nature.

The information is organized and presented in such a way that the thesis may be used as a handbook by the architect, engineer, contractor, or homeowner who is interested in making more sympathetic and creative use of a building site.

Thesis Supervisor: Prof. Edward Allen
Position: Professor of Architecture, M.I.T.

*in dedication to my parents;
for always being there.*

INTRODUCTION

There is beginning, today, a profound change in man's feeling about nature. The 19th century was a period when humankind was busily struggling to overcome natural hazards and natural disadvantages. The struggle was caused by a vague impression that natural forces and natural conditions were generally hostile, and thus factors to be fought or disregarded. Where humans begin to achieve dominance, the balance of nature is often disrupted: plant and animal worlds are made poorer; pools and streams are eliminated; irregularities in the type and form of grounds are smoothed out; even forests take on a cultivated appearance. "The site is rarely seen as an infinitely varied bit of the earth's surface, with slopes, rock outcrops perhaps, groups of trees or other native flora. A developer comes to a site with bulldozers and power shovels, with pickaxe, dynamite, and fire, and as rapidly and as cheaply as he can, he transforms what might have offered a superb challenge to imaginative design, into a flat and dreary waste of dirt." Indeed, architects are forever creating new kinds of microclimates. Every building constructed displaces the original climate of its site, creating a warm, sunny, and dry climate with a southern exposure on one hand, and a shady, cold, and damp northern exposure on the other. If we are going to replace the natural richness existing on a site, we must, with a powerful vocabulary, respect and create a replacement richness that once again can be called 'natural'. Architects must come to realize that man's future lies less in fighting natural forces and natural conditions, than in cooperating with them. They must realize that every variation in slope, every change in the character of the surface, and every natural peculiarity of a site may be the source of the most vivid and successful elements in a design.

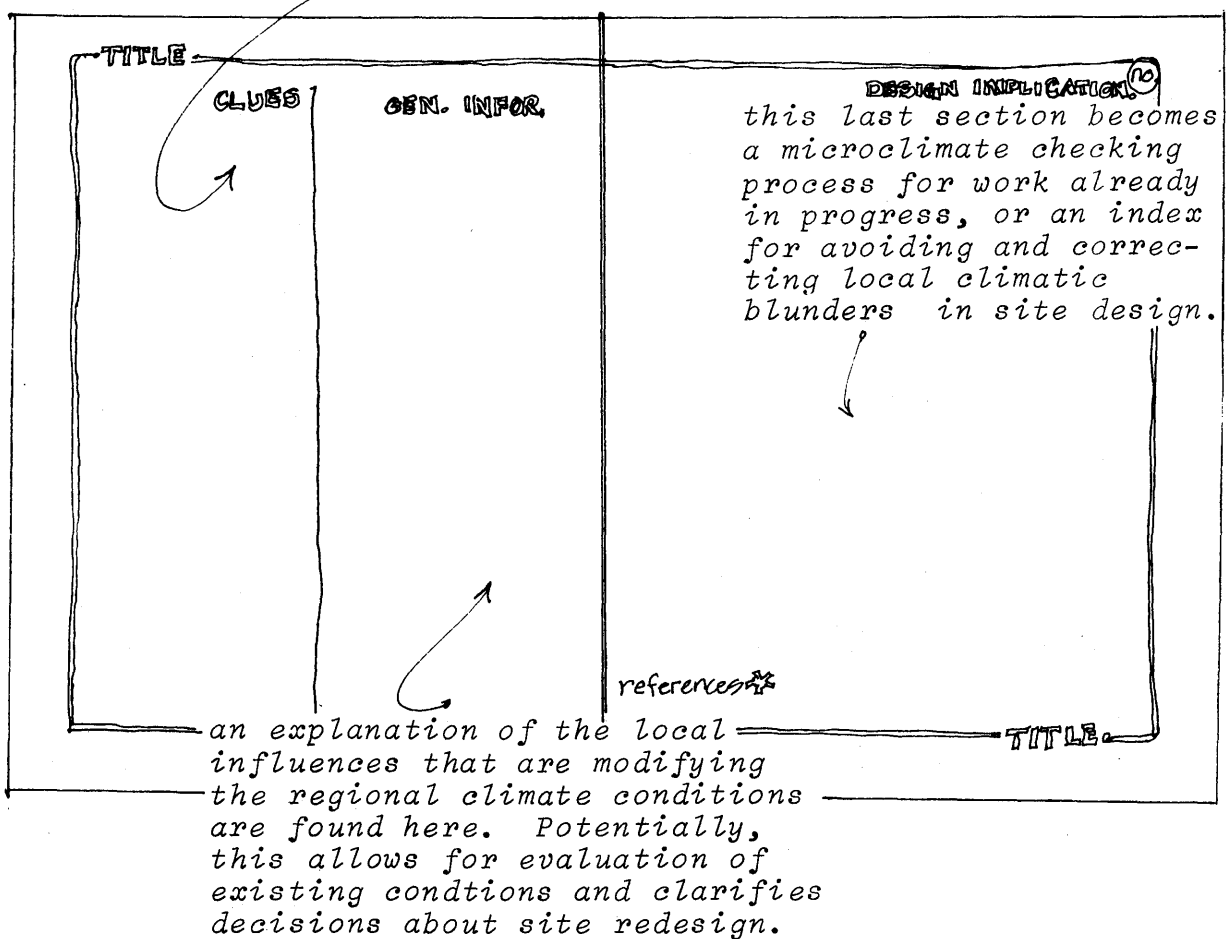
HOW TO USE THIS MANUAL:

The intent of this thesis is to sensitize architects, architectural students, engineers, planners, home builders, and homeowners, with the demands and phenomena of the large and small-scale climate, and to apply that knowledge in the design of sites, buildings, and communities. In order to do this, it is advisable to study a site in several ways over time, with different emphases. There is no simple method of site selection, analysis and design. Instead one needs to gain a total image of the particular site, and an understanding that allows the use of the natural site conditions to enhance the practicability and the livability of the built environment.

The text itself is divided into four major sections: vegetation, drainage, topography, and soils. Each of these issues is discussed in turn with respect to the four climatic elements that specify human comfort conditions: sun, temperature, wind, and moisture. The fifth chapter then takes the regional climate data related to these four elements, and reevaluates this data to approximate the microclimate conditions for the particular site.

Within each page, then, there are three levels of information, which can each be used for separate purposes:

prior to a site visit, one might skim these on-site clues as a means of identifying the habitable climate conditions on a given site. A heightened sensitivity as to the attributes and deficiencies of a site allows responsible decisions to be made in design. By all means do not level a site before it has a chance to speak for its strengths and weaknesses.



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Vegetation

Vegetation Classification:

BASIC TO THE UNDERSTANDING OF A SITE IS A KNOWLEDGE OF THE LOCAL VEGETATION: THE CONDITIONS IT RESPONDS TO, ITS CHARACTERISTICS, THE FUNCTIONAL DESIGN PROBLEMS IT SOLVES, AND HOW EFFECTIVELY.

N.E. IS TYPIFIED BY DRY LANDS, LANDS WHICH LACK STANDING OR SLOW FLOWING WATER MOST OF THE YEAR. AT THE NEXT SCALE, DRYLANDS ARE DEFINED BY THEIR VARIOUS CLOTHINGS INTO BARELANDS, HERBLANDS, SHRUBLANDS, & WOODLANDS.

BARELANDS

BARELANDS INCLUDE AREAS OF NON-VEGETATED MINERALS, ROCKS, OR SOIL. OFTEN CAUSED BY EROSION AND LOW PRECIPITATION, BARELANDS ARE ALSO A RESULT OF SOIL POISONING AND MAN'S REMOVAL OF VEGETATION.

- LYING EXPOSED TO THE SUN, BARELANDS ARE QUICKLY HEATED, WITH LIGHT COLORED LANDS REFLECTING MOST OF THE HEAT BACK INTO THE AIR, DARK LANDS ABSORBING THE HEAT FOR SHORT TERMS. DUE TO A LOW THERMAL CAPACITY, BARELANDS RERADIATE QUICKLY AND BECOME COLD, SOMETIMES CONDENSING MOISTURE.
- OF ALL THE BARELANDS POSSIBLE, STABILITY IS MAXIMUM ON BEDROCK, MINIMUM ON BARE ERODIBLE SANDS AND LOAMS.
- DRAINAGE RANGES FROM MAXIMUM RUNOFF ON IMPERVIOUS ROCK OR HIGHLY COMPACTED SOIL, TO MAXIMUM INSOAK IN SANDS.

CONSIDER THE RAPID HEATING AND COOLING OF BARELANDS THE UNHAMPERED WIND MOVEMENT, AND THE FAST DRYING ACTION.

HERBLANDS

HERBLANDS ARE VEGETATED AREAS WITH NON WOODY PLANTS—GRASSES, FLOWERS, AND WILD FLOWERS. THEY ARE AREAS WHERE SUN AND WIND ARE STRONG, SOMETIMES RELENTLESS. SINCE HERBS & GRASSES ARE SHORTER WITH LESS SURFACE FOR EVAPORATION, THEY ARE OFTEN FOUND THRIVING IN THE LESS HUMID AREAS WITH INSUFFICIENT WATER.

IN GENERAL, HERBS AND GRASSES HAVE FINE, FIBROUS ROOTS. THE ROOTS, STEMS, AND LEAVES PROTECT THE SOIL, KEEPING IT FROM BLOWING OR WASHING AWAY. AND KEEP THE SOIL POROUS, PROMOTING INSOAK AND LESSENING RUNOFF.

FINALLY, THE PRESENCE OF HERBLANDS STABILIZES THE WATER TABLE AND KEEPS SURFACE WATERS FILTERED.

SHRUBLANDS

SHRUBLANDS ARE VEGETATED BY WOODY PLANTS WITH TWO OR MORE STEMS EMERGING FROM THE SOIL AT GROUND LEVEL.

SHRUBS OFTEN COLONIZE AND SURVIVE IN SITES TOO DRY FOR FOREST GROWTH. EVEN WITH ADEQUATE RAINFALL, THERE MAY BE INADEQUATE SOIL MOISTURE DUE TO FAST PERCOLATION (IN POROUS SANDS FOR INSTANCE). IF TREES COULD GROW, SHRUBS WOULD THEN BE ONLY AN EARLY STAGE IN THE OVERALL VEGETATION. A SHRUB VEGETATION MAY BE PERMANENT WHERE WINDY OR DRY CLIMATES, FIRE, DISASTERS, OR POOR SOIL CONDITIONS RULE.

SHRUBS ARE THE MOST VALUABLE PROTECTORS OF SOIL, MINIMIZING WIND AND WATER EROSION, AND REGULATING THE FLOW OF WATER.

TREELANDS

FORESTS NEED MORE MOISTURE IN THE AIR AND IN THE SOIL THAN MOST OTHER TYPES OF VEGETATION. TREELANDS GROW WHERE THERE ARE 20 INCHES OR MORE OF RAINFALL PER YEAR, AND ENOUGH SOIL FOR ANCHORAGE AND SUSTENANCE.

- NARROW-LEAVED TREES (PINES, SPRUCES) ARE BETTER ADAPTED TO DROUGHTY CONDITIONS THAN BROADLEAVED OAKS AND MAPLES. FORESTS ARE STOPPED BY EXCESSIVE WINDS AT THE TIMBER LINE.

- OPEN-CANOPY TREELANDS ON SOIL WHICH IS DEEP FERTILE, AND MOIST ENOUGH FOR GROUND COVER AS WELL, CREATE STABLE WATERSHEDS BECAUSE OF ORGANIC MATTER ACCUMULATION, AND SOIL POROSITY DUE TO ROOT PENETRATION. IN MORE ARID PLACES, THERE WILL BE BARE AREAS BETWEEN THESE TREES, WITH RAPID RUNOFF, (WHICH MUST BE TERRACED, PLANTED, CONTOURED, OR MULCHED).

TREES ARE ONE OF THE BEST WAYS TO PREVENT EROSION, STABILIZE SOIL AND AIR TEMPERATURES, AND MANIPULATE THE SUN AND WIND CONDITIONS FOR THE BEST POSSIBLE RESULTS.

ALTHOUGH LESS COMMON IN NEW ENGLAND, WETLANDS ARE TYPIFIED BY SHALLOW WATER, FLOOD PLAINS, OR GROUND WATER THAT RISES SO HIGH AS TO BE NEAR THE SURFACE MUCH OF THE TIME. AS A RULE, WETLANDS ARE UNSUITED FOR BUILDING WITHOUT GREAT MODIFICATIONS.

references:
2, 3, 7, 14.

:Vegetation Classification:

Plants As Site Indicators:

IF THE IMPORT OF THIS STUDY CAN ONLY BE STRESSED THROUGH GENERALIZATIONS, THEN:

CLUES

←FOR FOUNDATION DESIGN→LOCATES

AS WELL AS LOOKING AT THE INDIVIDUAL TREES ON A SITE, LOOK AT THE VARIETIES IN:

- AGE: YOUNG TO MATURE TREES.
- DENSITY: FROM AREAS OF NO VEGETATION TO OPEN FIELDS TO DENSE WOODS.
- WEAR: SIGNS OF WEAR & STRESS.
- THE UNUSUAL: UNUSUAL SPECIMENS OR COLLECTIONS.

ADDITIONAL CLUES:

◦ RICH OAKS AND THEIR POOR RELATIVES:

WHITE, PIN, AND RED OAKS ARE FOUND IN DEEP, RICH, WELL DRAINED SOILS.

BLACK, CHESTNUT AND SCRUB OAKS WILL SCRABBLE IN THIN, DRY, DAMAGED SOILS TO TAKE ROOT.

◦ HICKORIES AS WELL GROW IN A VARIETY OF SOILS. W/SHAGBARK AND SHELBARK HICKORIES IN GOOD SOIL, AND RED AND BUTTERNUT HICKORIES IN POOR SOIL.

◦ A QUICK INDICATION OF WATER NEARBY (STREAMS, HIGH TABLES) ARE SUCH TREES AS: CANOE BIRCH, ARBORVITAE, RED & SILVER MAPLES, WILLOWS, DOGWOODS, & SYCAMORES. RED ASH TREES ALWAYS INDICATE A SURFACE BODY OF WATER NEARBY.

NEW ENGLAND TREES	SOIL TYPE	DRAINAGE INDICATED	MOISTURE NEEDED
ALDER	ANY EXCEPT CLAY	GOOD	WET
WHITE ASH	ANY	GOOD	MOIST
EUROP. BEECH	LOAMS	GOOD	DRY
CANOE BIRCH	ROCKY	SHALLOW	DRY
AMER. ELM	ANY	MED.	MOIST
HICKORY	ROCKY	MED.	DRY
HORSE CHESTNUT	LOAMS	MED.	MOIST
TREE OF HEAVEN	ANY	GOOD	DRY TO MED.
LINDEN	LOAMS	GOOD	MOIST
RED MAPLE	ANY	POOR	WET
SUGAR MAPLE	LOAMS	GOOD	MOIST
NORWAY MAPLE	LOAMS	MED. TO GOOD	MOIST
SYCAMORE MAPLE	POOR	POOR	MOIST
WHITE OAK	SANDY/ROCKY	GOOD	DRY
PIN OAK	SANDY/ROCKY	GOOD	DRY
SCRUB OAK	ANY	EXCELL.	DRY
SYCAMORE	LOAMS	POOR	MOIST
TULIP TREE	LOAMS	EXCELL.	MOIST
WILLOW	ANY	POOR	WET
AM. ARBORVITAE	LOAMS	POOR	MOIST
BOX ELDER	LOAMS	GOOD	MOIST
EAST. RED CEDAR	ANY	GOOD	DRY
EAST. HEMLOCK	ANY	GOOD	WET
WHITE FIR	ANY	GOOD	MOIST
DOUGLAS FIR	LOAMS	GOOD	MOIST
AUSTRIAN PINE	LOAMS	GOOD	MOIST
RED PINE	ROCKY/SANDY	GOOD	DRY
WHITE PINE	ANY	GOOD	DRY
SCOTCH PINE	LOAMS	GOOD	MOIST
JAP. BLACK PINE	LOAMS	GOOD	MOIST
PITCH PINE	ROCKY/SANDY	EXCELL.	DRY
JACK PINE	ANY	EXCELL.	DRY
RED SPRUCE	LOAMS	GOOD	MOIST

- PLANTS HAVE BOTANICAL AND HORTICULTURAL GROWTH CHARACTERISTICS WHICH CAN AND SHOULD BE AMPLY CLASSIFIED.
- PLANTS HAVE RELEVANT DESIGN CHARACTERISTICS SUCH AS FORM, COLOR, TEXTURE, ETC.
- PLANTS ARE RELIABLE INDICATORS OF VERY LOCAL SOIL, DRAINAGE, AND MICROCLIMATE CONDITIONS.
- PLANTS ALSO HAVE FUNCTIONAL CHARACTERISTICS WHICH AFFECT THE ENVIRONMENT.

WATER TABLE AND BEDROCK → ← MICROCLIMATE CONDITIONS →

ORGANIC SOIL CONTENT	ROOT TYPE	TEMP. HARDINESS (MIN. RANGES)	SUN NEEDED	SHADE PROVIDED	WIND BREAKAGE	POLLUTION HARDINESS
LITTLE	RADIAL - COARSE	-50° TO 10°	SUN	NO	YES	YES
MED.	TAP AND SURFACE	-50° TO -5°	SUN/SHADE	YES	LITTLE	YES
HIGH	DEEP RADIAL	-50° TO -10°	SUN	NO	NO	NO
LITTLE	SURFACE - FINE	-50° TO -5°	SUN/SHADE	YES	YES	MED.
MED.	RADIAL - FINE	-50° TO 10°	SUN/SHADE	NO	NO	YES
LITTLE	WHORLED - COARSE	-35° TO -5°	SUN/SHADE	YES	LITTLE	NO
MED.	SURFACE - COARSE	-35° TO -5°	SUN	YES	YES	MED.
LITTLE	WHORLED - COARSE	ANY	SUN/SHADE	YES	YES	YES
MED.	RADIAL - FINE	ANY	SUN/SHADE	YES	NONE	YES
ANY	SURFACE	-ANY°	SUN/SHADE	YES	YES	YES
HIGH	RADIAL	-50° TO -5°	SUN	NO	NO	NO
MED.	RADIAL - FINE	-50° TO -5°	SUN	YES	LITTLE	YES
LITTLE	SURFACE - COARSE	ANY	SUN/SHADE	YES	YES	YES
LITTLE	TAP & SURFACE	-35° TO -5°	SUN	YES	NO	NO
HIGH	SURFACE	-20° TO 10°	SUN/SHADE	NO	NO	MED.
LITTLE	WHORLED SURFACE	-35° TO 10°	SUN	NO	LITTLE	NO
ANY	COARSE DEEP RADIAL	ANY	SUN	NO	YES	YES
HIGH	FINE DEEP RADIAL	-35° TO 10°	SUN	NO	NO	NO
ANY	SURFACE - FINE	ANY	SUN/SHADE	NO	YES	YES
HIGH	SURFACE - FINE	-35° TO 10°	SUN	YES	NO	NO
HIGH	RADIAL - COARSE	-20° TO 5°	SUN	NO	YES	YES
LITTLE	SURFACE	-20° TO 10°	SUN	NO	NO	NO
HIGH	TAP AND SURFACE	-50° TO -5°	SHADE	YES	NO	NO
MED.	TAP	-20° TO 10°	SUN	YES	NO	NO
MED.	TAP AND SURFACE	5° TO 40°	SUN	YES	NO	NO
MED.	TAP	ANY	SUN	NO	NO	MED
MED.	TAP	-50° TO -5°	SUN	NO	YES	NO
ANY	TAP - WHORLED	-50° TO -5°	SUN	NO	NO	NO
MED.	TAP	ANY	SUN	NO	NO	NO
HIGH	TAP AND SURFACE	ANY	SUN	NO	NO	MED.
LITTLE	TAP	ANY	SUN	NO	NO	NO
LITTLE	TAP	-30° TO -5°	SUN	NO	NO	MED.
MED.	TAP	-35° TO 10°	SUN	NO	NO	NO

REFERENCES: 2, 3, 7, 14
+ TERRY SCHNADELBACH

Plants As Site Indicators:

Vegetation & Shading.

CLUES

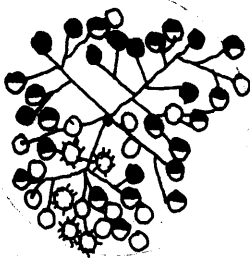
SUN LOVING PLANTS



USUALLY HAVE SMALL LEAVES SO THEY WILL NOT LOSE TOO MUCH MOISTURE FROM THE SUN.

SHADE-LOVING PLANTS HAVE LARGE LEAVES TO CATCH THE SUNLIGHT FROM UNDER THE CANOPY OF A THICK FOREST.

SOUTH SLOPES ARE LIGHTER COLORED, SINCE IN FULL SUN THE GREEN CHLOROPHYLL CELLS DO NOT NEED TO BE AS ABUNDANT AS IN SHADED LEAVES TO REAP THE BENEFIT OF THE SUN.



- 15 MAY
- 16 MAY
- 17 MAY
- 18 MAY

BLOSSOMING ALSO APPEARS TO DEPEND ON ORIENTATION. THE TIP OF THE CROWN WHICH RECEIVES SUNLIGHT ALL DAY, BLOSSOMS FIRST. FROM THEN ON, BLOSSOMING FOLLOWS A PATTERN OF MAXIMUM TEMPS.

RECOGNIZE THE PARTS OF THE SITE WHICH RECEIVE THE MOST RADIATION.

GENERAL INFORMATION

SOLAR SHADING & TEMPERATURE

IN GENERAL, THE SHADED SIDE OF A PLANT IS COOLER THAN THE RADIATED SIDE. LOW PLANTS AND GRASSY COVERS REDUCE TEMPERATURE BY SCATTERING LIGHT, ABSORBING RADIATION, AND BY THE EVAPOTRANSPIRATION PROCESS. IN FACT, GRASSY SURFACES ARE OFTEN 10° COOLER THAN BARE SOIL. VINES ALSO SERVE AS NATURAL COOLING DEVICES FOR WALLS, COOLING BY PROVIDING SHADE, AND BY EVAPORATION. IN THE DAYTIME, THE GROUND TEMPERATURE UNDER A THICK CANOPY OR THE TEMPERATURE OF A PROTECTED WALL, MAY BE AS MUCH AS 25° COOLER THAN THE EXPOSED TOP OF THE TREE.

DENSITY OF VEGETATION

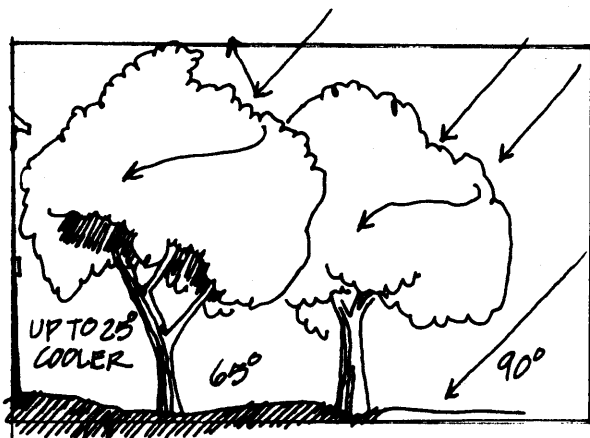
TREE DENSITY MAKES A SIGNIFICANT DIFFERENCE, WHEN SHADING IS BEING CONSIDERED (WITH CANOPIES AND WALLS), AND WHEN PLANT WINDBREAKS ARE TO BE EFFECTIVE. DENSITY DEPENDS ON:

1. LEAF SIZE AND ARRANGEMENT ON THE BRANCH
2. THE BRANCHING PATTERN AND SPACING, AND HEIGHT FROM THE GROUND,
3. THE NUMBER AND DISTANCE OF TREES, AND THEIR CANOPY DIMENSION.

	AMERICAN ARBORVITAE
	DOUGLAS FIR
	NORWAY MAPLE - SUMMER
	COLORADO BLUE SPRUCE
	WHITE OAK - SUMMER
	AMERICAN ELM - SUMMER
	GREY BIRCH - WINTER
	PIN OAK - WINTER
	MOUNTAIN ASH - WINTER
	BLACK LOCUST - WINTER

DESIGN IMPLICATIONS

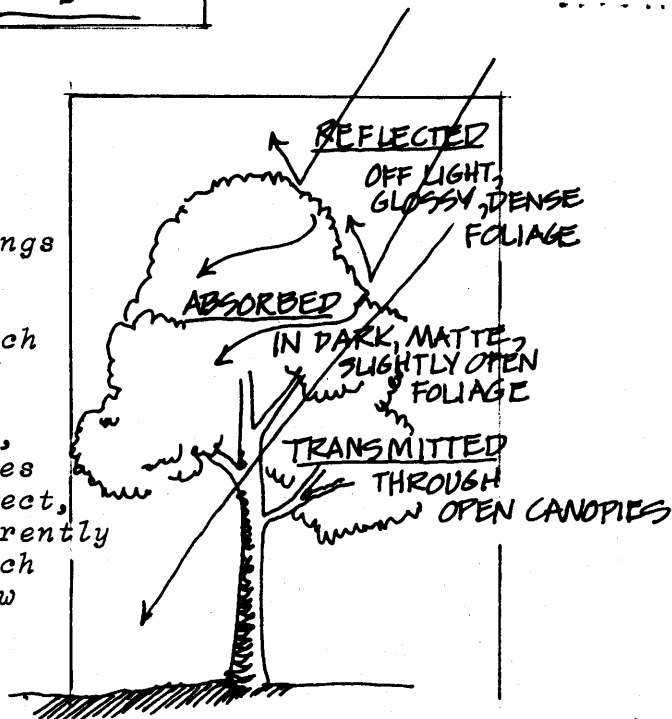
Snow will not melt quickly on the shaded side of evergreens. Thus, evergreens placed on the southern side of roads will leave long periods of snow and ice. This fact could be very useful, however, in the design of ski slopes.



Considerable temperature relief can be provided by use of vegetation near courts, parks, walls, and interior rooms to naturally modify the excessive heat and glare of the sun. Deciduous trees will screen the hot sun in summer, and allow warming rays to pass through bare branches in ^{winter} summer.

So, in addition to placing new buildings or new vegetation carefully in their relationship to each other, be aware of the choice in: Planting densities, colors, and textures which absorb, reflect, and transmit differently and tree forms which cast varying shadow dimensions.

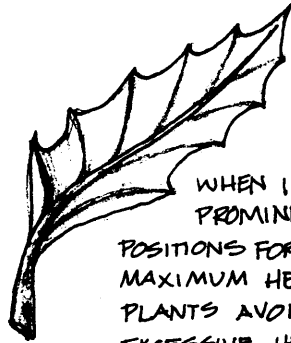
references: 2, 3, 12



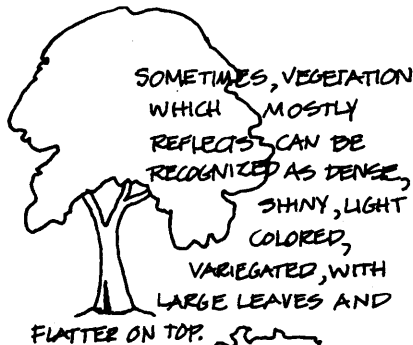
Vegetation & Shading

Vegetation & Heat Transfer:

GLUES

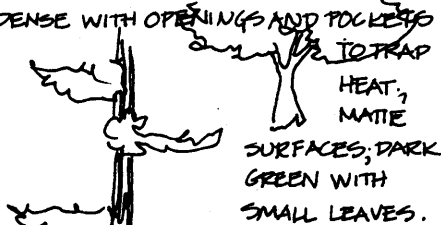


WHEN IN PROMINENT POSITIONS FOR MAXIMUM HEAT GAIN, PLANTS AVOID EXCESSIVE HEATING BY CORRUGATIONS OF THE LEAVES (NATURAL SHADOWING), BY PUBESCENCE (HAIRINESS), AND BY MOVEMENT.



SOMETIMES, VEGETATION WHICH MOSTLY REFLECTS, CAN BE RECOGNIZED AS DENSE, SHINY, LIGHT COLORED, VARIEGATED, WITH LARGE LEAVES AND FLATTER ON TOP.

VEGETATION WHICH ABSORBS OFTEN IS:



DENSE WITH OPENINGS AND POCKETS TO TRAP HEAT, MATTIE SURFACES, DARK GREEN WITH SMALL LEAVES.

PLANTS WHICH ALLOW RADIATION TO PENETRATE ARE OFTEN BARE OR THIN, OR WITH HIGH CANOPIES, THAT ALLOW LIGHT SEEKING PLANTS TO GROW BENEATH.

GENERAL INFORMATION

VEGETATION & INSULATION

BESIDES PROVIDING THE SHADING TO COOL THE GROUND BELOW, TREES AND TREE CANOPIES ACT AS AN INSULATION BUFFER BETWEEN GROUND AND SKY, INSIDE AND OUT. GROUND TEMPERATURE COULD BE UP TO 25° COOLER THAN THE TEMPERATURE AT THE TOP OF THE TREE CANOPY. HOWEVER, TEMPERATURES ARE NEARLY UNIFORM FROM TREE CANOPY TO TREE BASE, AS IN GOOD INSULATION DESIGN. IN ADDITION, THE MOISTURE CONTENT IN VEGETATION INCREASES THE ENTHALPY CONSIDERABLY. WATER RETAINS HEAT MUCH LONGER THAN AIR OR DRY LAND, KEEPING THE SURROUNDING ENVIRONMENT COOLER ON HOT DAYS, LATER RELEASING ITS HEAT TO THE COLDER NIGHT AIR. OVER ALL, VEGETATION SLOWS TEMPERATURE EXCHANGE - ACTING AS A NATURAL INSULATOR.

VEGETATION AS A HEAT SINK

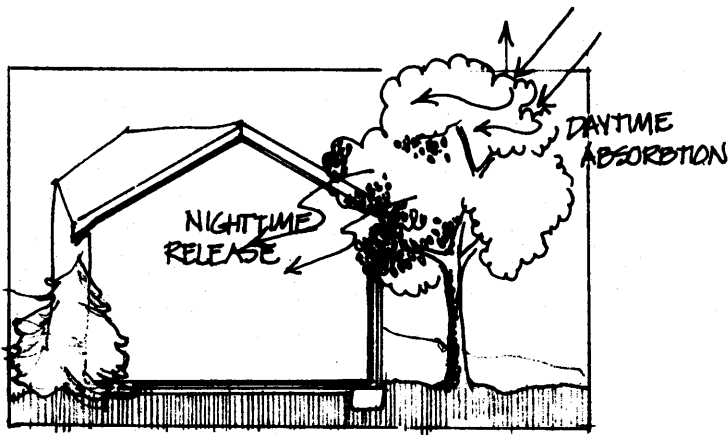
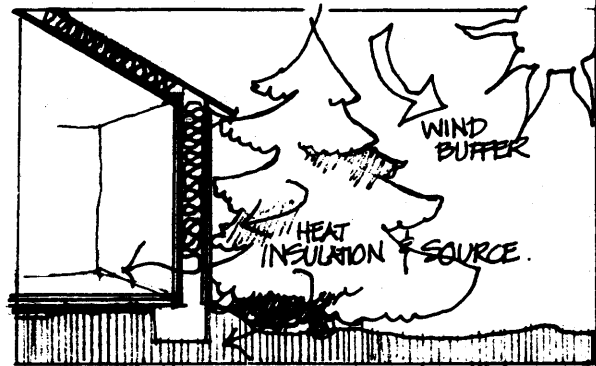
BY ABSORBING AND EMITTING RADIATION, BY EVAPORATING MOISTURE - LEAVES, NEEDLES, TWIGS, AND BRANCHES PLAY A SIGNIFICANT PART IN THE EXCHANGE OF HEAT WITH THE SURROUNDING AIR. WHEN RADIATION FALLS, PART OF IT IS REFLECTED - REPRESENTED AS A PERCENTAGE ALBEDO 'R'. ANOTHER PART PASSES THROUGH EXPRESSED AS 'D' THE PENETRABILITY COEFFICIENT. THE REMAINDER 'A' IS THE PERCENTAGE ABSORBED. R LIES BETWEEN 5 AND 30% AND EXCEPTIONALLY MAY RISE TO 60% ON THE LIGHTER SURFACES OF VARIEGATED LEAVES. THE AMOUNT OF RADIATION WHICH PENETRATES VARIES FROM 10-15%, LEAVING ABSORPTION AT GREATER 50 TO 60% MOST OF THE TIME. IT IS THIS ABSORPTION AND STORAGE THEN, THAT ALLOWS VEGETATION TO SERVE AS A HEAT SOURCE FOR COOLER PERIODS.

DESIGN IMPLICATIONS

5

THE TEMPERATURE OF AN AREA, OR A BUILDING WALL, IS DIRECTLY RELATED TO SOLAR RADIATION CONTROL, TO WIND AND AIR MOVEMENT CONTROL, TO PRECIPITATION AND HUMIDITY CONTROL, THE BASIC FUNCTIONAL USES OF VEGETATION.

Use plants as one type of wall insulation, a ground insulation near basements, thus retarding heat loss to the cooler air outside.



Vegetation can act as a heat retainer (especially when planting moisture-holding trees), and stabilize temperature differences, by long-term heat absorption.

references: 3,7,12

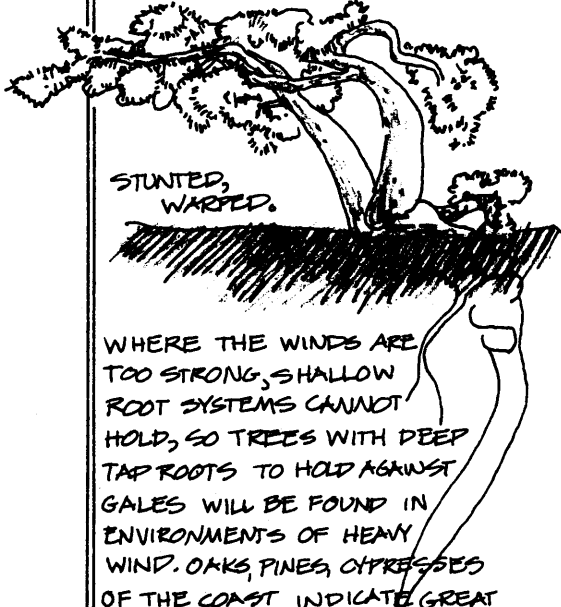
Vegetation & Heat Transfer

Vegetation & Air Movement:

CLUES

THE TEXTURAL DIFFERENCE BETWEEN FINE, MEDIUM, AND COARSE LEAFING ON TREES HAS MORE THAN VISUAL IMPLICATIONS. WIND BUFFERS AND EFFECTIVE SUN SHADES NEED NOT ONLY GREATER DENSITY IN LEAFING AND BRANCHING, AND PLACEMENT, BUT ALSO COARSER TEXTURES TO ACT AS STIFFER MEMBRANES AGAINST THE WIND.

- WIND IS A CARVER OF THE SHAPES OF TREES:



WHERE THE WINDS ARE TOO STRONG, SHALLOW ROOT SYSTEMS CANNOT HOLD, SO TREES WITH DEEP TAP ROOTS TO HOLD AGAINST GALES WILL BE FOUND IN ENVIRONMENTS OF HEAVY WIND. OAKS, PINES, CYPRESSES OF THE COAST INDICATE GREAT WINDS AND THEIR TWISTED SHAPES REFLECT IT.

*A TOUGH-BARKED TREE IS MORE RESISTANT AGAINST HIGH WINDS, BECOMING MORE DOMINANT THAN THIN-BARKED TREES ON WINDY SITES.

GENERAL INFORMATION

TEMPERATURE & AIR MOVEMENT

A BASIC PROPERTY OF AIR MOVEMENT IN RELATION TO TEMPERATURE, IS THAT HIGH WIND SPEEDS THERMODYNAMIC EXCHANGE, WITH RESULTING LOSS OF INTERNAL HEAT OR NEEDED COOLNESS. VEGETATION CAN SLOW, STOP, AND REDIRECT WIND, OR EVEN INDUCE AIR MOVEMENT TO SPEED UP.

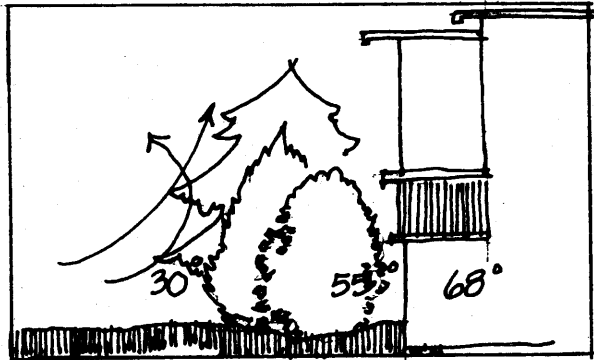
SLOWING THE WIND

IS ESPECIALLY USEFUL IN THIS WINTER-HEAVY CLIMATE. BY REDUCING THE AIR SPEED, LESS HEAT IS CARRIED AWAY FROM THE BUILDING FACE, RESULTING IN LOWER HEATING NEEDS FOR THE BUILDING.

STOPPING THE WIND

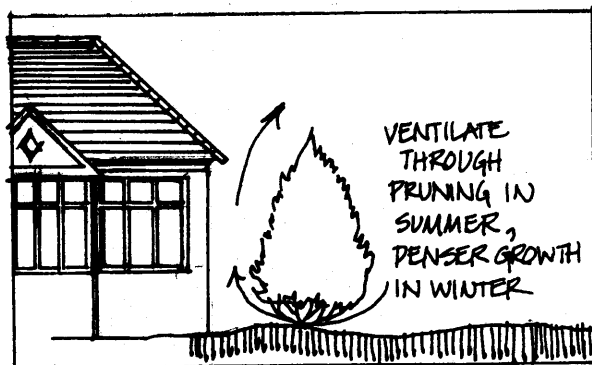
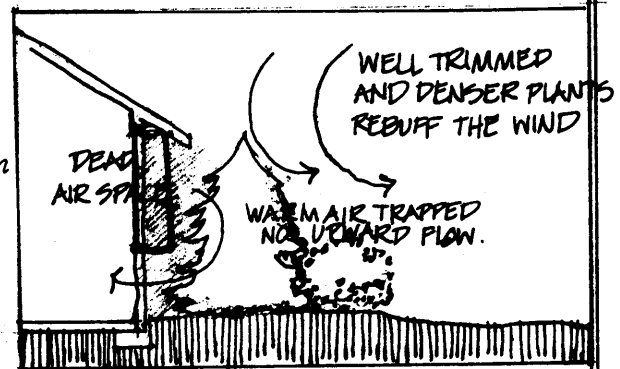
WITH DEAD AIR INSULATION CAN PROVIDE A REDUCED TEMPERATURE GRADIENT (DIFFERENCE), ALSO PREVENTING THE ESCAPE OF HEAT FROM A BUILDING. EVERGREENS, FOR EXAMPLE, PLANTED CLOSE TO A WALL OF A BUILDING WILL CREATE DEAD AIR SPACES AND INSULATE THE BUILDING FROM ABRUPT ENERGY CHANGES. THE EVERGREENS, THEN MAY ALSO BE USEFUL FOR COOLING IN SUMMER BY SHADING AND TRANSPIRATION. ON SOUTH WALLS, THE USE OF EVERGREENS MUST BE WEIGHED AGAINST THE ADDED ADVANTAGE OF HEATING THE WALL BY DIRECT SOLAR RADIATION IN WINTER. IN NORTHERN ORIENTATIONS, EVERGREENS ALSO INSULATE THE GROUND - KEEPING ITS WINTER TEMPERATURE HIGHER, WITH LESS FROST, FREEZING AND SURFACE TEMPERATURE VARIATION.

DESIGN IMPLICATIONS



Use edge planting to insulate buildings and prevent rapid heat exchange, by retarding wind movements across the building face.

In winter allow less air to circulate, pooling instead the warm air, to prevent a drop in temperature. Be careful not to place vegetation poorly, thereby drawing cold air into a pocket; and do not leave too large a space, allowing cold air to fill in and dam.



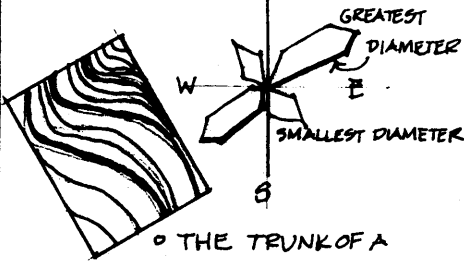
In summer, on the other hand, allow some air to pass through at a low level. This prevents excessive humidity harmful to the structure, and forces up the hot air with cooler incoming breezes.

ref: 3, 7, 0, 12

: Vegetation & Air Movement:

Designing Windbreaks:

CLUES



◦ THE TRUNK OF A TREE IS USUALLY OVAL IN CROSS-SECTION, NOT CIRCULAR. ON LEVEL GROUND, THE MAXIMUM DIAMETER IS USUALLY IN THE DIRECTION OF THE PREVAILING WIND. THE CROSS-SECTIONS OF TREES STANDING ON SLOPES ARE NO LONGER CONTROLLED BY WIND DIRECTION BUT BY LIGHT RECEIVED, WHICH FOLLOWS THE LINE OF STEEPEST SLOPE.



◦ TEXTURE WHILE TEXTURED PLANTS SLOW AND REDIRECT WIND SPEEDS, A WELL TRIMMED STREAMLINED COLLECTION OF PLANTS WILL ACTUALLY SPEED UP WIND FLOW, LEAVING A CONTRASTING AREA OF LOW PRESSURE IN BACK & RESULTING IN SUCTION EDDIES ON THE LEEWARD SIDE OF THE WINDBREAK.

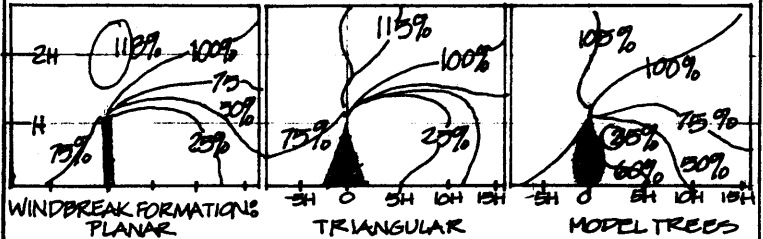
GENERAL INFORMATION

REDIRECTING THE WIND

REDIRECTING THE WIND IS THE FINAL PROPERTY OF GOOD VEGETATION DESIGN AND PLACEMENT. A THICK BELT OF PLANTS CAN BE EFFECTIVE WINDBREAKS, REDUCING VELOCITIES 50% FOR UP TO 12 TIMES THEIR HEIGHT. SHELTER BELTS ARE MOST EFFECTIVE WHEN PLACED PERPENDICULAR TO THE PREVAILING WINDS, DEPENDENT ON THE HEIGHT, WIDTH, AND PENETRABILITY OF PLANTS.

FORM OF WINDBREAKS

IN GENERAL, SHELTER BELTS SHOULD BE DEEP, RISING GRADUALLY ON THE WINDWARD SIDE, DROPPING ON THE LEEWARD SIDE; AND SOMEWHAT OPEN BELOW TO ALLOW ENOUGH AIR THROUGH TO STOP LEEWARD TURBULENCE.

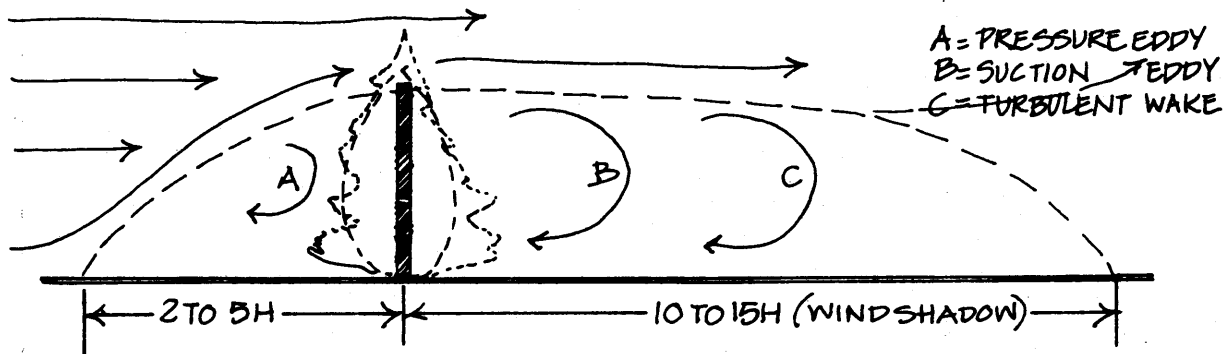


IN ORDER TO EFFECTIVELY DESIGN WIND BREAKS, ONE MUST NOTE THE EFFECT OF SHAPE ON AIRFLOW. NOTE ① THE CONDITIONS ON THE WINDWARD SIDE OF THE BARRIER, AND DESIGN NEEDS THERE; ② THE INCREASE IN WINDSPEED ABOVE THE BARRIER AND HOW THIS MIGHT AFFECT TALLER BUILDINGS LOCATED BEHIND; AND ③ THE DISTANCE BEHIND THE BARRIER WHICH IS PROTECTED, AND TO WHAT DEGREE.

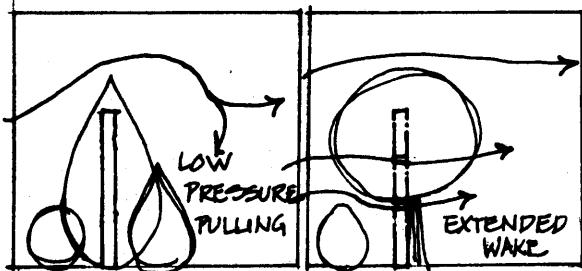
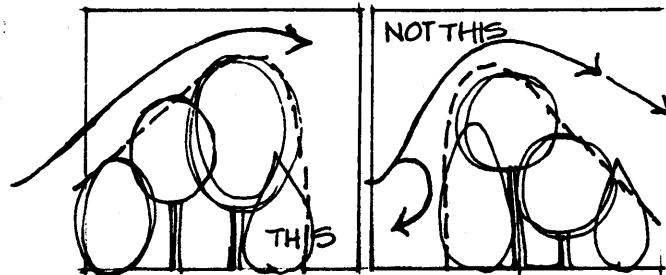
PLANTS TO USE

SELECT SPECIES FOR GROWTH FORM, DENSITY, AND HARDINESS. CONIFEROUS EVERGREENS THAT BRANCH TO THE GROUND ARE GENERALLY THE MOST EFFECTIVE YEAR-ROUND PLANTS FOR WIND CONTROL. A MIXTURE OF NUMEROUS SPECIES AND SIZES OF PLANTS WITHIN A WINDBREAK PRODUCES A ROUGH UPPER SURFACE AND IS MORE EFFECTIVE IN CONTROLLING WIND.

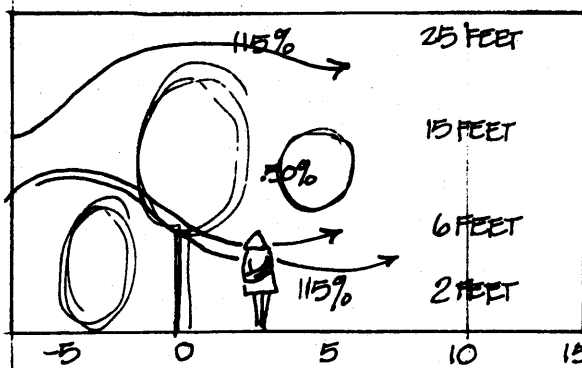
DESIGN IMPLICATIONS



Use vegetation to create wind protected areas and building walls. Mass a variety of vegetation to sweep the air up over an area, but not to fill the protected wake.



A somewhat pierced windbreak eliminates the low pressure pocket on the leeward side of the barrier. This places less drag on the air flow above, giving a longer wake of quieter air and protected space. Also avoid no pressure pockets between plant windbreaks and the building wall.

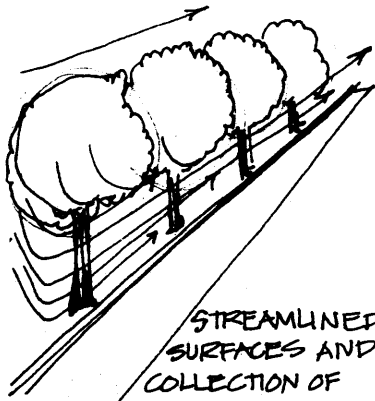


Although windbreaks may decrease air velocities to the depth desired, they can also increase wind speeds in neighboring areas and at different heights. Consider the effect of windbreaks at foot height, head height, and upper story window height.

references: 5,12

Inducing Wind Movement:

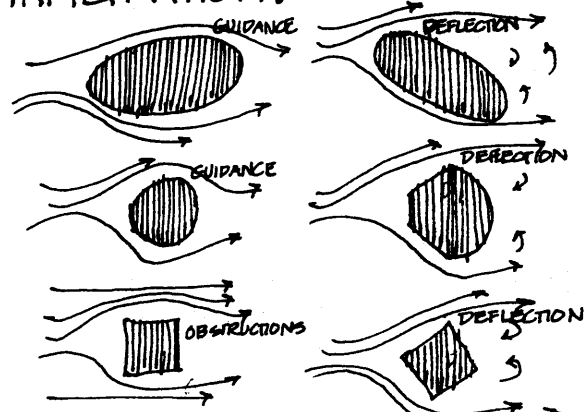
CLUES



STREAMLINED SURFACES AND A COLLECTION OF DENSE CANOPIES WILL SPEED UP WINDS BY COLLECTING WIND CURRENTS ABOVE, BELOW, AND AROUND, AS WELL AS OFFERING LITTLE FRICTIONAL OBSTRUCTION.

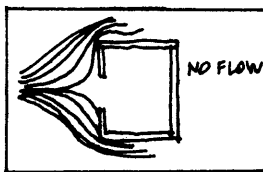
GENERAL INFORMATION

PLANTS CONTROL WIND BY OBSTRUCTION, GUIDANCE, DEFLECTION, AND INFILTRATION.

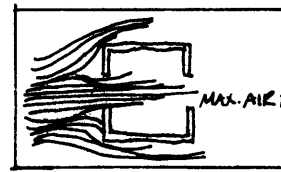


(see micro: climate)

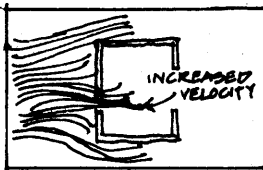
WIND MOVES AT A SLOW TANGENT TO THE OBJECT IN ITS PATH, BUILDING UP SPEEDS WHEN DIRECT AIR FLOWS IN CONTINUOUS LINES. WHEN THIS OCCURS, WINDS CANNOT FOLLOW UNEXPECTED DIRECTION CHANGES - LEAVING WINDLESS POCKETS & EDDIES.



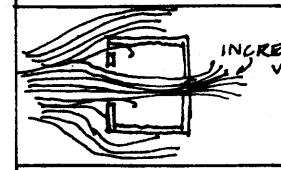
1. TO RECEIVE AIR FLOW, AN AREA MUST HAVE BOTH INLETS AND OUTLETS. HERE NO FLOW OCCURS ACROSS THE SITE.



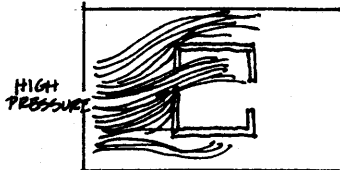
2. MAXIMUM AIR FLOW OCCURS WHEN LARGE OPENINGS OF EQUAL SIZE ARE PLACED OPPOSITE EACH OTHER.



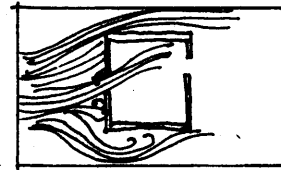
3. HIGHEST SPEEDS OCCUR WHEN A SMALL INLET IS COMBINED WITH A LARGE OUTLET.



4. LARGE INLETS WITH SMALL OUTLETS CAUSE HIGH SPEEDS BEYOND THE SITE.

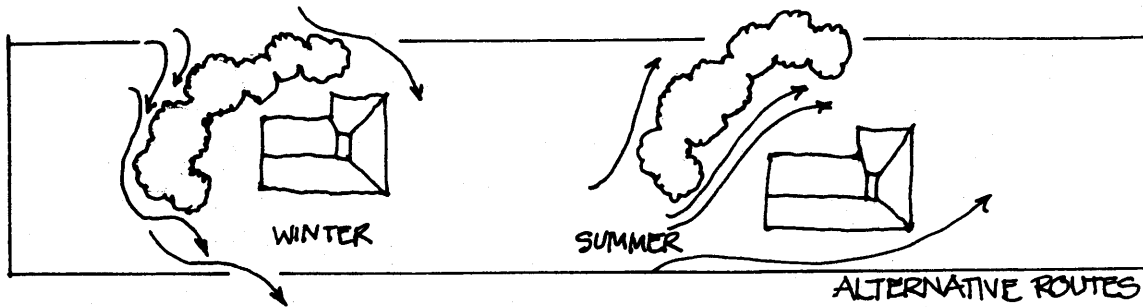


5. AN OFFSET CAUSES ASSYMETRICAL FLOW. THE OUTSIDE HIGH PRESSURES FORCE AIR FLOW AT AN ANGLE.

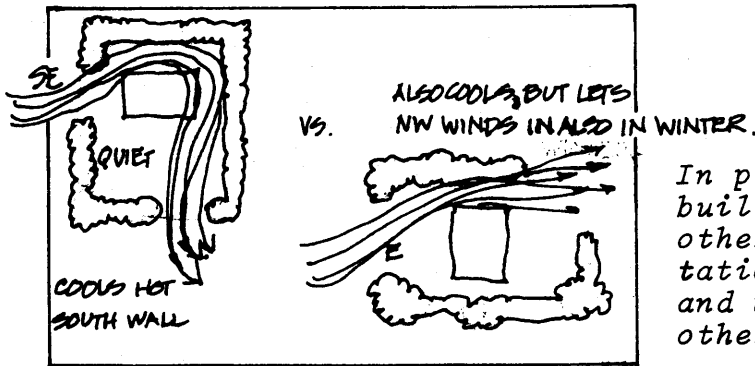


6. ASSYMETRICAL FLOW ALSO OCCURS WHEN EXTERIOR VECTORS CAUSE SIDE PRESSURE.

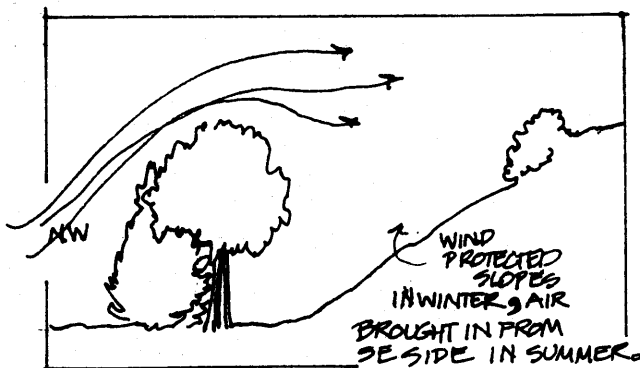
DESIGN IMPLICATIONS



With careful wind observation, plants can be used to obstruct and redirect the wind, leaving places and building faces free of wind; as well as to catch the wind, and ventilate hot stuffy areas.



In plan, place vegetation and buildings in relation to each other to maximize use of vegetation when needed in summer, and minimize wind movement otherwise.



In section, as well, plants can be used to cause a beneficial change of direction in the airflow within and around a site. This provides one method of protecting slopes, roof surfaces, and raised terraces from higher wind speeds.

references: 12, 14

(see: microclimate & winds)

Inducing Wind Movement:

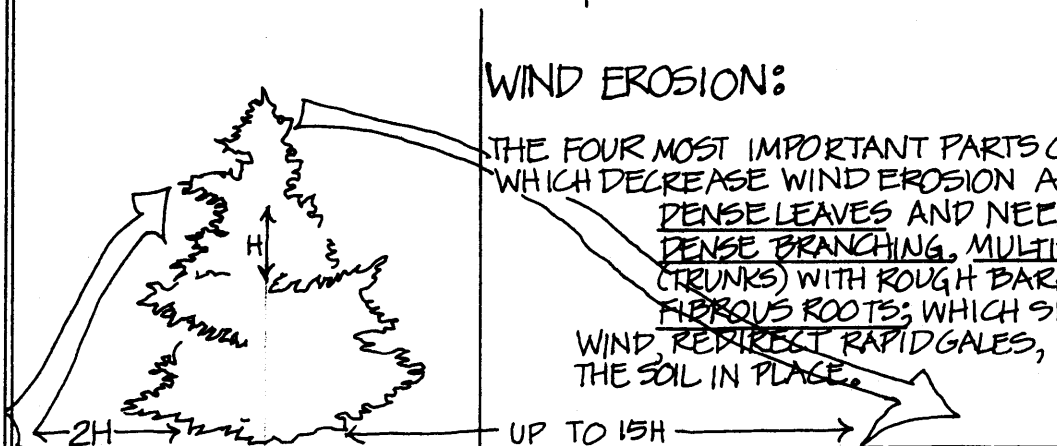
Vegetation & Erosion Control:

GENERAL:

TYPE OF SOIL, LENGTH AND DEGREE OF SLOPE, SUN, WIND, AND RAIN CONDITIONS ALL HAVE A MAJOR INFLUENCE ON SOIL AND BUILDING EROSION. IN PREVENTING THIS EROSION, BUILDING CORROSION, OR UNDERMINED FOUNDATIONS, VEGETATION HAS A LOT TO OFFER:

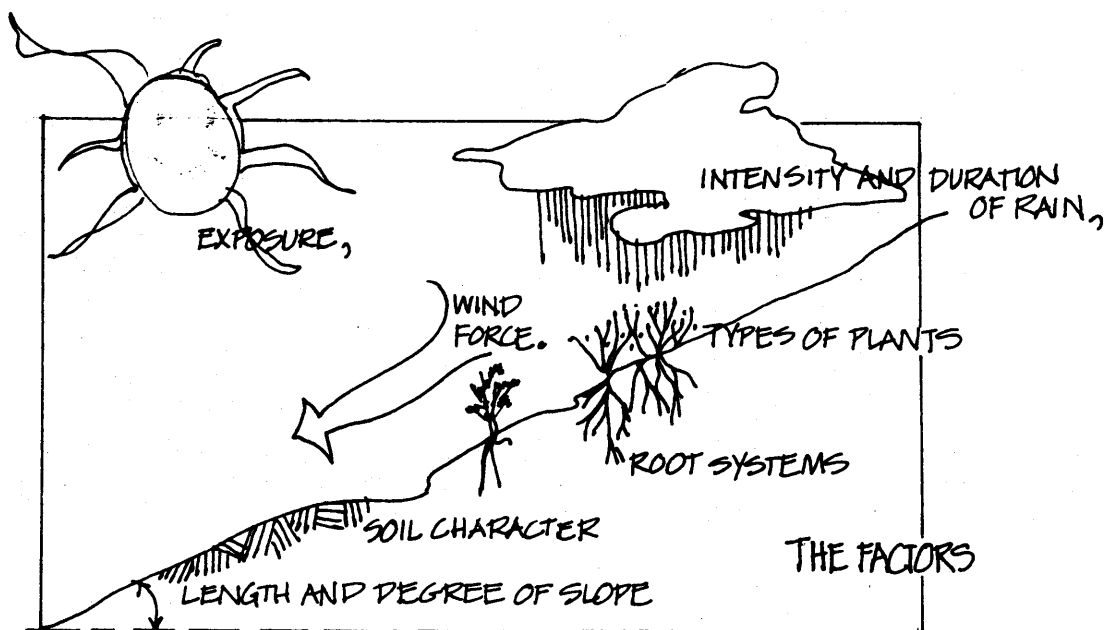
SPREADING PENETRATING ROOTS HOLD SOIL.
PUBESCENT (HAIRY) LEAVES HOLD THE DUST AND POLLUTION WHICH CORRODES.
LEAVES, BRANCHES & TRUNK PATTERN STOP THE RAPID FALL OF PRECIPITATION, AND SLOW ERODING WINDS. THEY ALSO FILTER LIGHT AND SUN EXPOSURE.

WIND EROSION:



THE FOUR MOST IMPORTANT PARTS OF PLANTS WHICH DECREASE WIND EROSION ARE:
DENSE LEAVES AND NEEDLES,
DENSE BRANCHING, MULTIPLE STEMS (TRUNKS) WITH ROUGH BARK, AND
FIBROUS ROOTS; WHICH SLOW THE WIND, REDIRECT RAPID GALES, AND HOLD THE SOIL IN PLACE.

- UPWIND, THE AREA PROTECTED BY A PLANT WINDBREAK IS TWICE THE HEIGHT (H), AND DOWNWIND UP TO 15 TIMES THE HEIGHT OF THE WINDBREAK.
- EVEN TWO-INCH BARE SPOTS BETWEEN LOW (GRASS) VEGETATION COVER, CAUSES EXCESSIVE DRYING, LEVERAGE FOR UPROOTING, AND SOIL EROSION.



WATER EROSION:

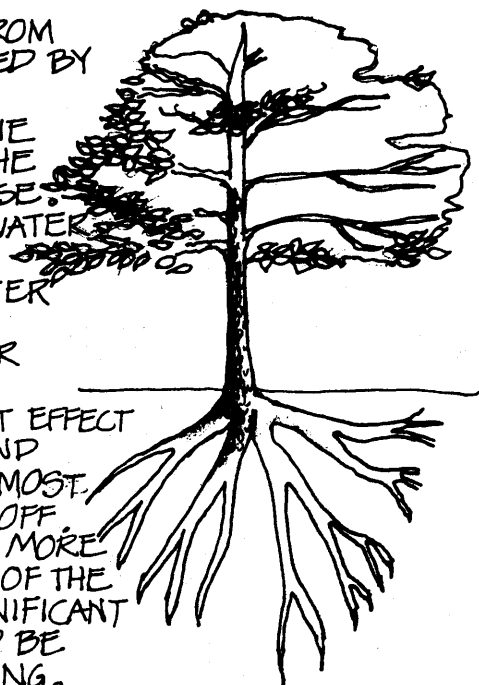
SIMILAR TO WIND EROSION, EROSION FROM SURFACE PRECIPITATION CAN BE CONTROLLED BY SEVERAL FACTORS:

HORIZONTAL BRANCHING IS MOST EFFECTIVE IN PREVENTING WATER RUNOFF DOWN THE TREE TRUNK, CAUSING EROSION AT THE BASE. ROUGH BARK ALSO HOLDS AND SLOWS THE WATER RUNNING DOWN THE TRUNK.

LEAVES VARY IN THEIR ABILITY TO HOLD WATER AND BREAK RAIN VELOCITIES.

DENSITY OF CANOPY WILL DETERMINE WATER IMPACT ON THE GROUND. &

ROOT CHARACTER HAS A VERY SIGNIFICANT EFFECT ON WATER EROSION - BOTH THE SURFACE AND SUBSURFACE RUNOFF. FIBROUS ROOTS ARE MOST EFFECTIVE FOR HOLDING SOIL IN SURFACE RUNOFF. HOWEVER, DEEP ROOTS AND TAP ROOTS ARE MORE EFFECTIVE IN SLOWING THE FAST DRAINAGE OF THE SUBSURFACE WATERSHED. THIS HAS A SIGNIFICANT EFFECT ON FOUNDATION DESIGN, AND SHOULD BE CONSIDERED WHENEVER GRADING, LEVELLING, OR CHANGING THE NATURAL LANDSCAPE.

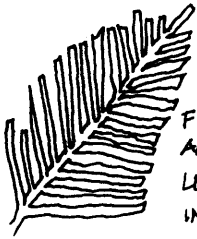


references:
2, 3, 12, 13

Vegetation & Erosion Control:

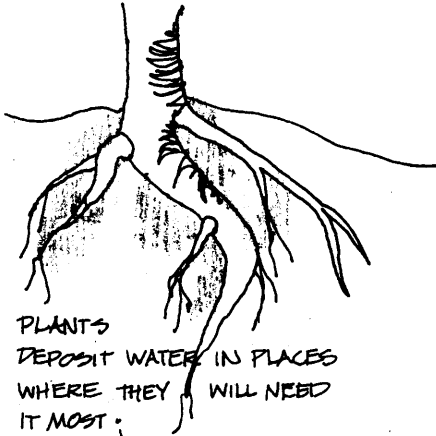
Vegetation & Moisture:

CLUES



FERNS, MOSSES,
AND LARGE
LEAVED VINES
IN THE
UNDERGROWTH
OF WOODS,

ARE SIGNS OF HEAVY RAINFALL
(730" A YEAR). WIDELY SPACED
TREES WITH FEW SHRUBS
INDICATE 15-30 INCHES.



PLANTS
DEPOSIT WATER IN PLACES
WHERE THEY WILL NEED
IT MOST;
THUS, THE HIGHEST MOISTURE
A FEW HOURS AFTER THE RAIN
IS NOT ADJACENT TO THE PLANTS
WHERE IT FELL UNHINDERED,
BUT UNDER THE ROOTS. FOR THIS
REASON, DRYNESS OF SOIL IN
THE NEIGHBORHOOD OF TAP
ROOTS IS COMMON.

GENERAL INFORMATION

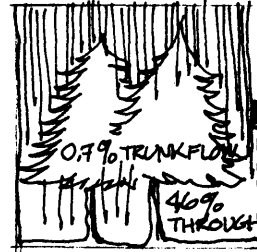
BY TRAPPING, HOLDING, AND TRANSPIRING
WATER, VEGETATION TEMPERA THE
HUMIDITY AND MOISTURE OF A SITE.

STOPPING, TRAPPING RAINFALL

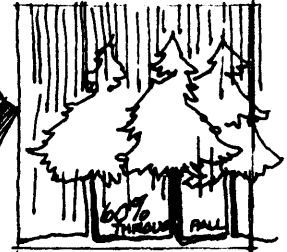
PLANTS CAN PREVENT SOIL EROSION, HUMIDIFY AND
WARM AREAS, BY SLOWING OR SHUTTING OUT
PRECIPITATION AND RUNOFF. THE DRIER SOIL
BENEATH TREES IS LESS SUSCEPTIBLE TO
FREEZE IN WINTER, AND EROSION AT ALL TIMES.
THE MORE HUMID AIR SURROUNDING, DUE
TO TREE DAMPNESS, WILL BE WARMER AIR.



AUSTRIAN PINES



DOUGLAS FIR



TYPICAL CONIFEROUS
FOREST

HUMIDIFYING

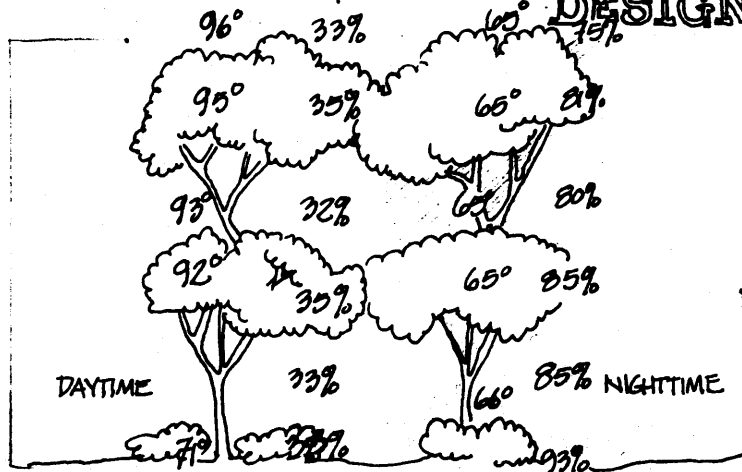
BY CREATING A PARTIALLY CLOSED SYSTEM BETWEEN
CANOPY AND GROUND, AND BY PREVENTING SOLAR
DRYING BY SHADING - VEGETATION ALSO LEAVES
A MORE HUMID ENVIRONMENT BENEATH TREE
CANOPIES. THIS STABILIZES TEMPERATURES AND
IS ESPECIALLY USEFUL IN COLD CLIMATES WHERE
HUMIDITY IS DESIRED. THEN, DRYING WINDS CAN
BE BROUGHT THROUGH TO ALLEVIATE THE HIGHER
HUMIDITY OF SUMMER.

TRAPPING, GATHERING MOISTURE

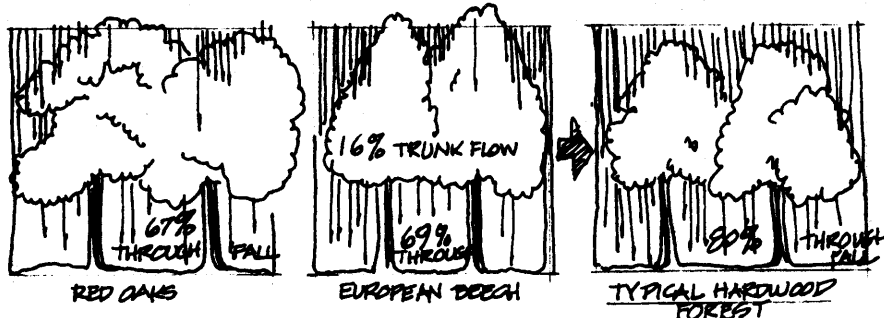
TREES AND SHRUBS SERVE TO PREVENT
EVAPORATION OF MOISTURE FROM THE SOIL BACK
INTO THE ATMOSPHERE. IN FACT, TREES INCREASE
MOISTURE CONTENT IN THE SOIL THROUGH SHADING
OF THE GROUND, AND THROUGH ROOT SYSTEMS
WHICH COLLECT WATER AND PREVENT RUNOFF.

TEMPERATURE VARIATION & HUMIDITY VARIATION

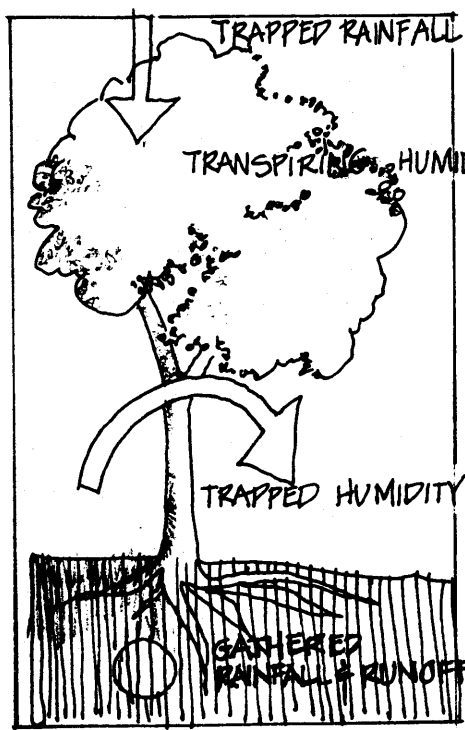
DESIGN IMPLICATIONS



Water has an excellent thermal capacity, equalizing temperatures over a period of time. Therefore, by maintaining a higher humidity, the area directly around trees usually has a less drastic temperature shift from day to night, adding significantly to the comfort of the area.



RAIN PENETRATION



Use trees of appropriate densities and moisture retaining ability to dry the areas beneath the canopy, and prevent surface erosion.

Design to trap humidity with canopies. When drying is needed in summer, allow then for the wind to sweep through.

In general, even grasses are worth planting for the benefit of their root systems in holding moisture and preventing runoff.

references:
312, 14

Vegetation & Moisture

Conditioning The Air:

CLUES

TREES TOLERANT OF
POLLUTION: SULFUR DIOXIDE
HYDROGEN FLUORIDE
OZONE

WHITE SPRUCE

RED PINE

RED MAPLE

SUGAR MAPLE

WILLOW

AMERICAN LINDEN

WHITE DOGWOOD

RED OAK.

IF THERE IS A SCARCITY OF SPECIES ON THE SITE, AND ONLY A FEW OF THESE HARDY TREES REMAIN, IT IS A CLEAR SIGN OF INCREASING POLLUTION.

GENERAL INFORMATION

POLLUTION CONTROL

VEGETATION CAN PURIFY THE AIR AND REGULATE POLLUTION BY THREE BASIC PROCESSES:

OXYGENATION. OXYGEN-DEFICIENT AIR CAN BE ENRICHED WITH THE OXYGEN GIVEN OFF BY CO₂ BREATHING PLANTS.

DILUTION. JUST AS MECHANICAL SYSTEMS MIX FRESH AIR INTO AN AREA CONTAINING IMPURE AIR, PLANTS CAN ALSO MIX AIRS WHICH PASS THROUGH AND AROUND THEM.

FILTRATION. LEAVES, BRANCHES AND TRUNKS WITH THEIR TEXTURE AND PUBESCENCE (FUZZINESS) WILL TRAP PARTICLES OF: DIRT, ASH, DUST, POLLEN, SMOKE, GASES, ODORS AND FUMES. THEN THROUGH TRANSPIRATION, THESE PARTICLES ARE REMOVED MUCH LIKE THE EFFECT OF AN AIR WASHER IN MECHANICAL AIR CONDITIONERS.

DRYING, HUMIDIFYING

BECAUSE PLANTS TRANSPIRE WATER INTO THE ATMOSPHERE, CAUSE AN INCREASE IN PRECIPITATION, AND RETAIN THE MOISTURE IN THE EARTH LONGER, VEGETATION SERVES AS A NATURAL HUMIDIFIER.

IN ADDITION, CAREFULLY PLACED VEGETATION CAN BE EFFECTIVE FOR DRYING IN SUMMER AS WELL. WELL TRIMMED AND DENSE SHRUBBERY CAN DIRECT AND SPEED DRYING-SUMMER WINDS THROUGH THE BUILDING OR SITE.

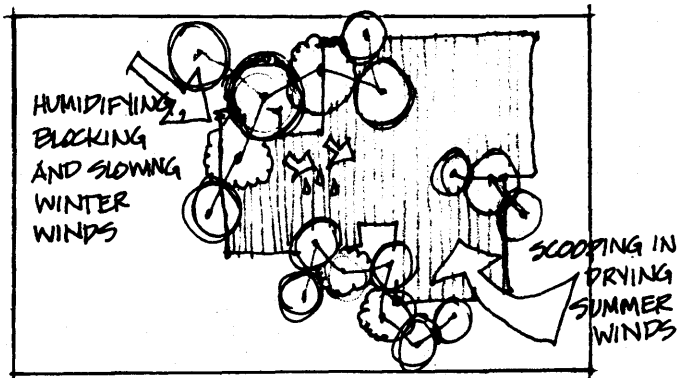
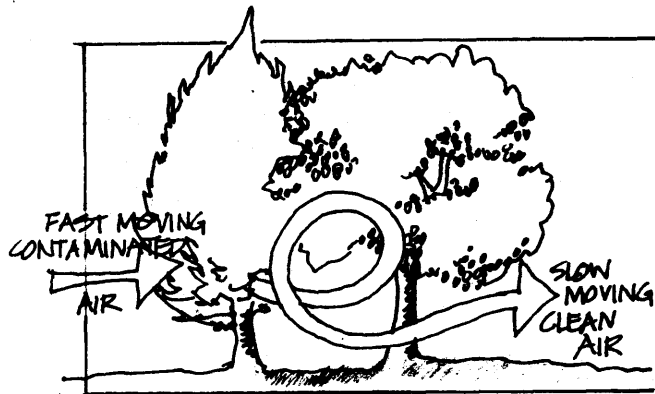
HEATING, COOLING

IN REVIEW, VEGETATION CAN HELP HEAT SPACES BY SLOWING AND REDIRECTING COLD WINTER WINDS, AND BY HEAT RETENTION (ACTING AS A THERMAL MASS) TO DIMINISH THE OVERALL TEMPERATURE EXTREMES. VEGETATION CAN ALSO BE USED TO COOL IN SUMMER BY SHADING TO COOL BUILDING WALLS AND NEIGHBORING GROUNDS AND BY REDIRECTING OR SCOOPING SUMMER BREEZES INTO A SPACE OR ACROSS A BUILDING FACE.

DESIGN IMPLICATIONS

PLANTS CAN HEAT, COOL, HUMIDIFY, DEHUMIDIFY, CLEAN AND CIRCULATE AIR AS WELL AS COMMERCIAL AIR HANDLERS OR AIR CONDITIONERS. PLANTS CONTROL TEMPERATURE, AIR FLOW, MOISTURE CONTENT.

Through careful placement of vegetation with respect to pollution sources—building exhausts, traffic or polluted winds—air can be purified and freshened for adjacent areas or rooms. Vegetation can control both natural and manmade pollutants, absorb noxious gases, act as a receptor of dust and dirt, as well as wash the air of impurities. Up to 30% of dust and smoke particles can be eliminated through an effective use and density of vegetation.



Good site design should:

- 1) induce winter winds to pass through vegetation. This slows and humidifies the air during the winter, when it is most effective for warming.
- 2) and should also involve placing vegetation (including deciduous or newly-trimmed plants) to direct drying summer winds through an overly humid space.

references: 12

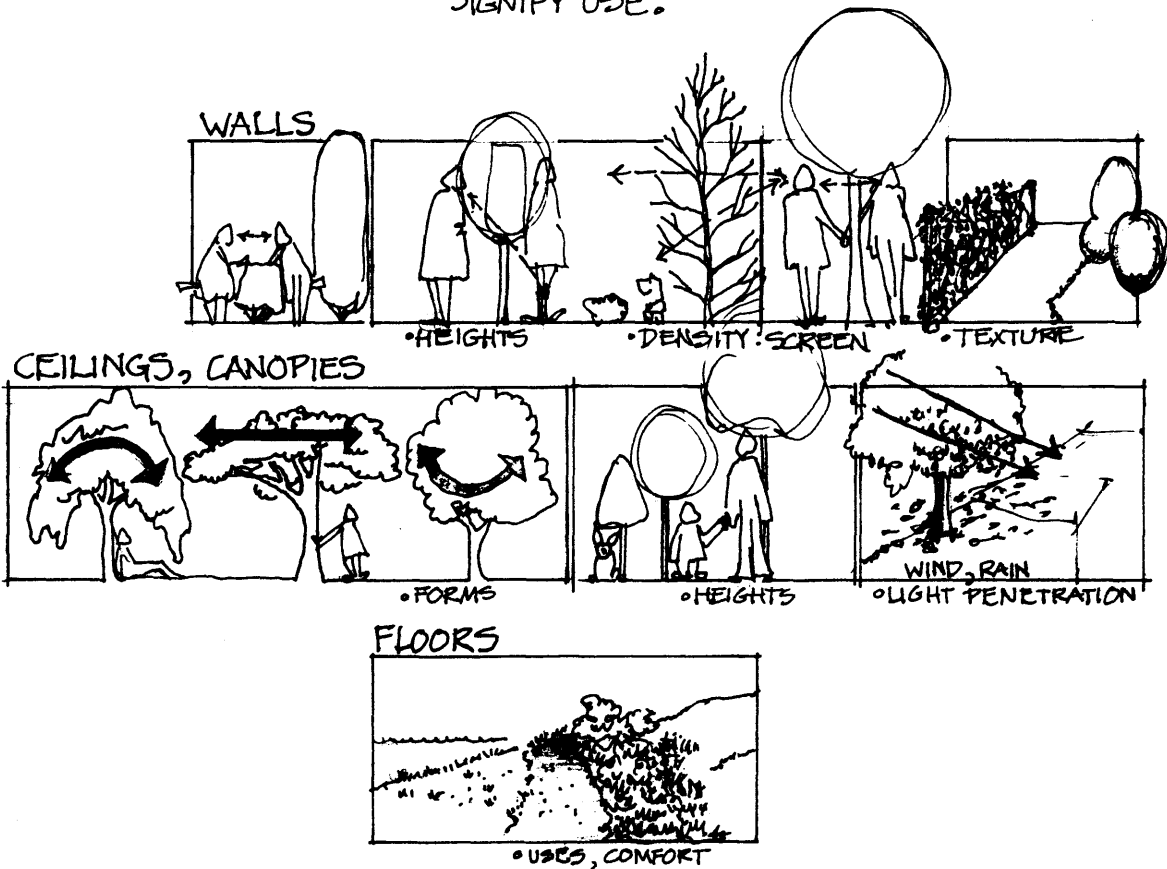
: Conditioning The Air:

Vegetation & Built Form:

IF DESIGN IS PARTLY TO MODIFY THE ELEMENTS, TO DIRECT, SLOW AND CONDITION THE SUN AND WIND, TO RESPOND TO NATURAL & PSYCHOLOGICAL NEED IN PLACE DEFINITION, THEN THE FORM AND PLACEMENT OF VEGETATION IS WELL WORTH CONSIDERING...

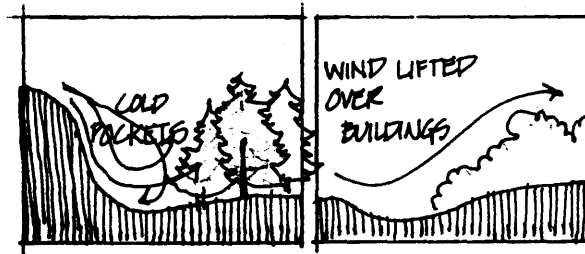
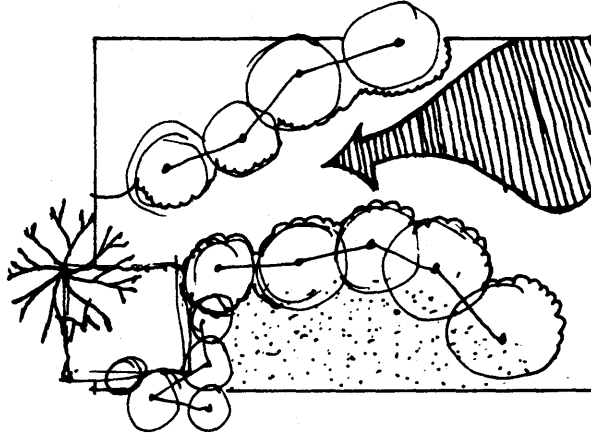
ARCHITECTURAL CHARACTERISTICS

- **WALLS:** TO DEAL WITH THE WIND & SUN, TO CREATE A VARIETY OF PLACE DIMENSIONS AND PROTECTION.
- **CANOPIES, CEILING:** VERSUS THE SUN, RAIN AND WIND, TO PROVIDE A VARIETY OF SPATIAL VOLUMES.
- **FLOORS:** TO PREVENT EROSION AND RAPID HEAT LOSS (STEADYING TEMPERATURES), TO SIGNIFY USE.



Vegetation acts in plan
:to channel, rebuff and
direct air and sun move-
ment;

:to create places that
will dynamically change
with each season, and
with each year.



Vegetation acts in section to build up land forms, to create a topography that can be more beneficial for building and placemaking. However, care must be taken not to create disadvantageous land forms.

THERE IS MORE EXISTING BUILT FORM ON THE SITE THAN IS FIRST APPARENT, AND OFTEN WITH RICHER DETAIL, AND MORE PRECIOUS AND TIME-CONSUMING WORKMANSHIP THAN COULD EVER BE BUILT IN. AS BUILT FORM, VEGETATION IS SUGGESTIVE OF OR BEGINNINGS FOR BUILDING SOLUTIONS.

references:

Vegetation & Built Form:

13

Drainage

Surface-Water Drainage:

CLUES

EROSION CLUES:

THE MOST PATHETIC RESULT OF POOR DRAINAGE DESIGN IS THE UNCONTROLLED DUMPING OF WATER WASTE WHICH HAS BEEN COLLECTED AND CHANNELED. TO CORRECT THIS RUNOFF SITUATION BEFORE THE WATER CAN UNDERMINE BUILDINGS AND SITES, LOOK FOR HINTS OF WATER STRESS IN THE LANDSCAPE. RECHANNELED OR INCREASED RUNOFF WILL:



- DEFORM OR UPROOT VEGETATION, ALTER WATER TABLES, CREATE GULLEYS AND EROSION CHANGES IN THE LOCAL TOPOGRAPHY.
- EROSION OCCURS WHENEVER THE RATE OF RAINFALL IS GREATER THAN THE INTAKE CAPACITY OF SOILS. SHEET FLOW EROSION WILL CARRY OFF ALL THE TOPSOIL, WHILE CHANNELIZED FLOW EROSION DEVELOPS WHEN IRREGULARITIES IN THE LAND OR BUILT SURFACE CONCENTRATE THE WATER ALONG CERTAIN LINES (EFFECTIVELY, REINFORCING THE LAND FORMS).

AFTER RAINS:

WHEREVER WATER REMAINS IN POOLS LONG AFTER RAINS, THERE IS POOR SURFACE DRAINAGE. THIS SITUATION MUST BE EITHER CORRECTED OR AVOIDED IN BUILDING.

GENERAL INFORMATION

ONE OF THE MOST INCONSISTENT & LOCALIZED PROBLEMS ENCOUNTERED ON A SITE IS DRAINAGE. INDEED, THE WATER PROFILE OF ANY PARTICULAR SITE INVOLVES 3 VARIABLES: THE SURFACE DRAINAGE CONDITIONS, THE GROUND DRAINAGE CONDITION (Pg.) AND THE WATER TABLE (Pg.).

SURFACE-WATER DRAINAGE RESULTS WHENEVER THE VOLUME OR THE SPEED OF THE DRAINING WATER EXCEEDS THE INFILTRATION RATE OF THE SOIL. IN ABSORPTIVE SOILS, SURFACE WATER WILL SINK INTO THE GROUND ALMOST AT ONCE, AND DRAIN SIMPLY. IN THE CASE OF IMPERVIOUS OR ALREADY SATURATED SOILS, OR IN FAST-FLOWING RAINS, WATER IS FORCED TO SEEK OTHER DRAINAGE PATTERNS. THIS RESULTS IN SURFACE WATER CONDITIONS RANGING FROM STANDING WATER (CAUSING CORROSION & WATER PENETRATION) AT ONE END OF THE SCALE, TO FORCEFUL DOWNHILL RUNOFF (WHICH ERODES SOIL & UNDERMINES BUILDING FOUNDATIONS) AT THE OTHER END.

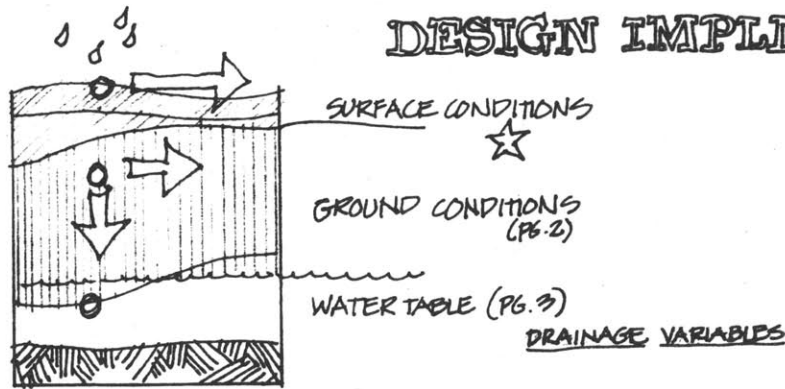
A. SURFACE RUNOFF

THERE ARE FOUR VARIABLES WHICH AFFECT THE SPEED AND QUANTITY OF SURFACE RUNOFF:

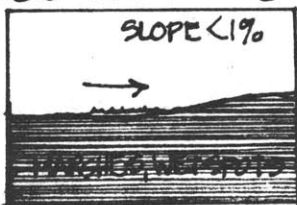
- SLOPES: SURFACE WATER DRAINAGE REQUIRES A CRITICAL SLOPE OF 1% TO PREVENT WET SPOTS, BUT LESS THAN 50 OR 60% TO PREVENT EXCESSIVE RUNOFF AND EROSION.
- SOILS: THE REPLACEMENT OF AN EXISTING ABSORBING SOIL WITH COMPACTED OR IMPERVIOUS SURFACES (ASPHALT ETC) OR OVERTILLED, EXHAUSTED SOILS, MAY INCREASE RUNOFF TO 100%.
- TEXTURES: ROUGH SURFACES CAN SLOW RUNOFF VELOCITY, OR REROUTE RUNOFF, OR CATCH DRAINAGE-WATER JUST LONG ENOUGH TO ALLOW FOR INFILTRATION.
- VEGETATION: VEGETATION SIGNIFICANTLY SLOWS AND ABSORBS SURFACE RUNOFF. DEFORESTATION CAN BE AS DAMAGING TO A SITE AS A MAJOR FLOOD.

B. STANDING SURFACE WATER CAN INCLUDE SMALL PUDDLES ON ROOFS AND PAVEMENTS WITH POOR DRAINAGE, OR PERCHED LAKES ON CLAY LINERS OR ROCKS. IF WELL LOCATED, LARGE STANDING BODIES OF WATER CAN STABILIZE AIR TEMPERATURES BY LONG-TERM HEAT RETENTION, WHILE UNEXPECTED POOLS CAN CAUSE SERIOUS CORROSION OF SOILS AND SURFACES, AS WELL AS CRACKING AND PENETRATING FOUNDATIONS.

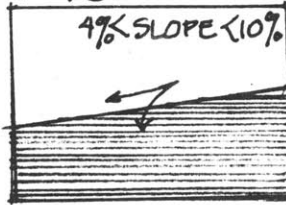
DESIGN IMPLICATIONS



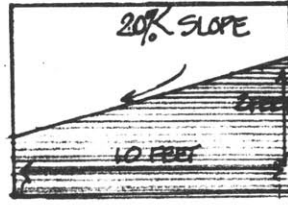
SURFACE CONDITIONS:



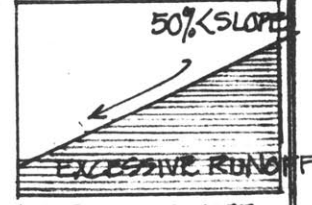
STANDING WATER.
NEEDS DRAINAGE
PROVISIONS.



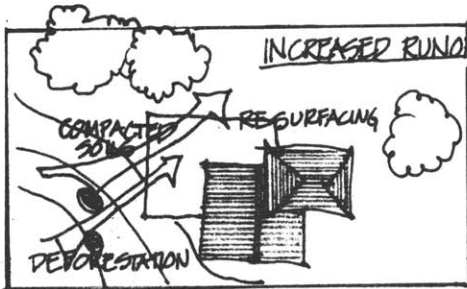
COMFORTABLE
ACTIVITY



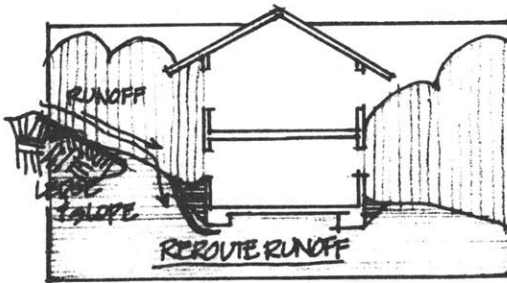
WILL NEED
PROTECTION FROM
EXCESSIVE RUNOFF
IN HEAVY RAINS.



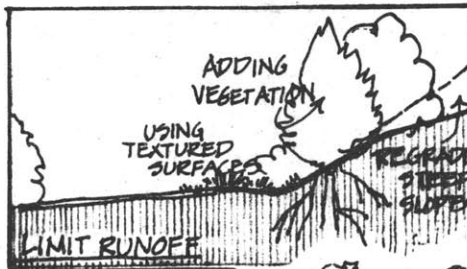
EXCESSIVE RUNOFF
CAN ONLY BE PROTECT-
ED BY TERRACING,
CRIBBING OR REGRADING.



Whenever possible, preserve the existing surface drainage courses. Through deforestation, resurfacing, building placement, or soil compaction in construction, drainage channels are often filled or blocked, forcing water to seek new (often damaging) runoff channels.



If building and surface placement must be in direct line with drainage channels, adequate gutters must be provided to direct surface water away from the building. Take particular care when buildings are placed halfway down or at the bottom of steep slopes, as foundations will be subject to severe undermining or corrosion.



Prevent slow, uncontrolled runoff by: regading steep slopes, limiting impermeable surfaces (e.g. concrete, asphalt), using textured surfaces, and adding vegetation whenever possible.

Surface-Water Drainage:

Ground Water Drainage :

CLUES



• IN AREAS WITH MODERATE RAINFALL, THE PERSISTENCE OF PUDDLES ON SURFACES IS A CLEAR INDICATION OF POOR INFILTRATION.



• STREAMS ARE A SIGN OF LOCAL GROUND WATER STORAGE, WITH NEARBY SOILS SUBJECT TO BOTH RUNOFF AND LEACHING TRANSPORTATION

GENERAL INFORMATION

INFILTRATION: THE AMOUNT OF INFILTRATION INTO THE SOIL'S GROUND STORAGE OR BELOW GROUND TRANSPORT, DEPENDS ON SEVERAL VARIABLES:

- 1) SOIL TYPE (POROSITY)
- 2) COMPACTION (UNDER CARS, PEOPLE, CATTLE)
- 3) LOOSE DUST & FINE PARTICLES WHICH CLOG PORES.
- 4) SUN CRACKS (IN DRY CLAYS), SURFACE FISSURES, DEPRESSIONS.
- 5) SLOPE. - ON STEEP SLOPES, WATER MOVES RAPIDLY WITH NO OPPORTUNITY FOR INFILTRATION, WHILE ON SHALLOW SLOPES WATER MOVES SLOWLY OR POUNDS.
- 6) FROST, SURFACE FREEZING, MAKES SOILS IMPENETRABLE.
- 7) CULTIVATION - REDUCES INFILTRATION BY ADDING AIR AND SMALL PARTICLES; INCREASES INFILTRATION BY TERRACING.
- 8) SURFACE COVER - VEGETATION AND SNOW WILL HELP WATER SLOW AND DISPERSE, WHILE HARD ROADWAYS INCREASE RUNOFF.
- 9) PREVIOUS SATURATION

STORAGE: IS DEPENDENT UPON THE POROSITY OF THE SOIL, AND IS STORED IN TWO WAYS:

- ① BY ADHERING TO SOIL PARTICLES BY SURFACE TENSION, OR BY CAPILLARY FORCES IN THE SPACES BETWEEN PARTICLES.
- ② BY FILLING CAVITIES IN THE SOIL, OR BY SITTING ON IMPERVIOUS LAYERS WHICH ARE PERCHED ABOVE THE ACTUAL WATER TABLE.

THERE IS A MAXIMUM TO THE WATER STORAGE CAPACITY, KNOWN AS ITS SATURATION, WHICH WHEN REACHED WILL REQUIRE GROUNDWATER TRANSPORTATION.

TRANSPORTATION: THE TRANSPORTATION OF GROUND WATER INVOLVES MOVEMENT IN THREE DIRECTIONS:

UP: BY CAPILLARY RISE WHICH IS EASIEST IN SAND, LESS EASY IN LOAM, MOST DIFFICULT IN CLAY.

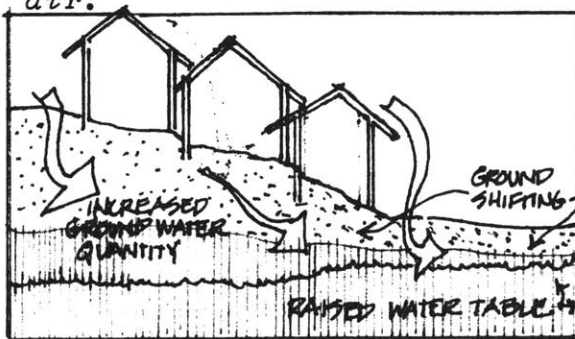
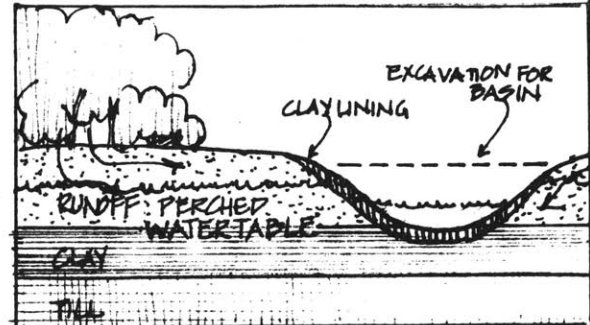
DOWN: AT A RATE WHICH DEPENDS ON THE PERCOLATION ABILITY OF THE SOIL PROFILE; FLOWING DOWN UNTIL IMPERMEABLE SOILS, OR THE WATER TABLE IS REACHED.

OUT: BY RUNOFF OR LEACHING. SLOPED LAYERS OF IMPERVIOUS SOILS, HIGH WATER TABLES, OR BEDROCK CAN CAUSE RUNOFF, WHILE OUTWARD LEACHING DEPENDS ON THE SAME GOOD PERCOLATION NEEDED TO MOVE IN ALL DIRECTIONS. GROUNDWATER RUNOFF CAN BE AS DETRIMENTAL AS SURFACE RUNOFF WITH UNPREDICTABLE OR NEWLY DETOURED RUNOFF STREAMS SUBJECTING BASEMENTS TO UNEXPECTED WATER CONDITIONS, SOIL SHIFTING, AND PRESSURES.

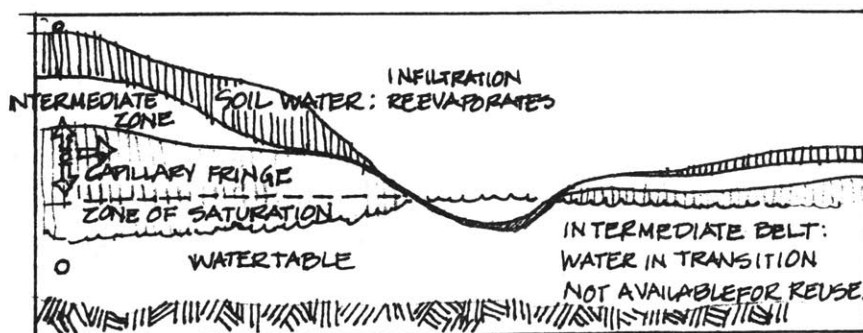
DESIGN IMPLICATIONS

Again, improve infiltration where runoff is excessive, by: terracing or regrading steep slopes, adding vegetation and grasses, and loosening or exchanging dense soils with layers of more porous materials.

If possible, store excess water near the ground surface by linings of less porous soils. This will prevent fluctuating water tables below, stabilize air temperatures, and warm and humidify the surface air.



The pressure of underground watercourses is particularly serious for siting structures. If, as a result of construction, both infiltration and ground water levels increase, prevent the new water transportation from shifting neighboring subsoils or causing water table fluctuations. Even on level sites, footing drains are necessary to remove subsurface runoff water, before it has time to damage foundations.



ref: 6, 7, 13, 21

Ground Water Drainage:

The Water Table:

CLUES

IDENTIFYING THE WATER TABLE LEVEL:



- THE EXISTENCE OF SEEPS AND SPRINGS, MOTTLED SOILS, AND SWAMPY VEGETATION IS AN INDICATION OF A HIGH WATER TABLE.

- AN EXISTING WELL OR A SIX FOOT TEST PIT WOULD REVEAL A WATER TABLE HIGH ENOUGH TO BE A SERIOUS PROBLEM FOR LOW-RISE DESIGN.



(A TEST PIT OF 1/2" DIAMETER AND 6 FEET DEEP WOULD BE ADEQUATE TO INDICATE A DANGEROUS WATER TABLE DEPTH.)

GENERAL INFORMATION

THE WATER TABLE

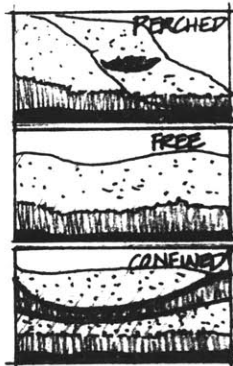
STANDING GROUNDWATER ESTABLISHES THE WATER TABLE, THE PLANE LOCATED AT VARYING DISTANCES BELOW THE SURFACE, BENEATH WHICH ALL PORES AND INTERSTICES BETWEEN SOIL GRAINS ARE FILLED WITH WATER. THE LEVEL OF WATER VARIES FROM SEASON TO SEASON, RISING IN TIMES OF HEAVY RAIN. IN GENERAL, HOWEVER, THE SOIL BELOW THE WATER TABLE LINE WILL BE WET AND WILL EXERT A HYDROSTATIC PRESSURE EQUAL TO A POOL OF WATER 433 LBS/FT. OF DEPTH.

LOCATING THE WATER TABLE: THE DEPTH OF THE WATER TABLE CAN VARY MARKEDLY, BUT ROUGHLY FOLLOWS THE CONTOURS OF THE OVERLYING SITE; AND SLOPES DOWN TO INTERSECT THE GROUND SURFACE AT PONDS, LAKES, STREAMS. ALTHOUGH THIS BOUNDARY IS DIFFICULT TO PINPOINT, THE LOWER LIMIT IS ALWAYS THE ZONE IN WHICH THE INTERSTICES ARE SO FEW AND SMALL THAT DOWNWARD MOVEMENT IS IMPOSSIBLE (SUCH AS ROCK, DENSE CLAY) THIS RESULTS IN THREE TYPES OF WATER CONFINEMENTS:

A PERCHED TABLE EXISTS ON A NON-CONTINUOUS LAYER WHICH IS BOWLED ENOUGH TO CONFINE WATER.

A FREE TABLE IS THE TYPICAL CONDITION OF WATER SATURATION OVER A CONTINUOUS IMPERVIOUS SOIL.

A CONFINED TABLE HAS NOT ONLY ITS LOWER BOUNDARY DEFINED, AS ABOVE, BUT ALSO A CONFINING STRATUM ABOVE WHICH FORMS AN ABSOLUTE BARRIER TO GROUNDWATER MOVEMENT.



WHAT AFFECTS THE WATER TABLE DEPTH:

FLUCTUATIONS ARE GREATER IN FINE TEXTURED SOILS (SILTS, CLAYS) THAN IN COARSE TEXTURED MATERIALS (GRAVELS), BECAUSE OF THE DIFFERING DIMENSIONS OF INTERSTITIAL VOIDS. OTHER INFLUENCES INCLUDE:

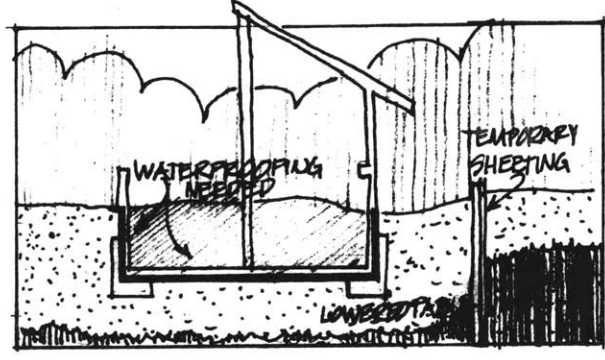
- VARYING AMOUNTS OF PRECIPITATION & EVAPORATION.
- A CHANGE OF SOIL TYPES ALLOWING INFILTRATION VS. RUNOFF.
- THE ADDITION OF WATER TO THE AREA: MAN-MADE LAKES AND IRRIGATION.
- PUNCHING HOLES, WELLS, OR PUMPING FOR CONSTRUCTION.
- VARIATION IN TOPOGRAPHY: DEPRESSIONS IN CLOSE PROXIMITY OF SATURATED SOILS OR WATER TABLE.

DESIGN IMPLICATIONS

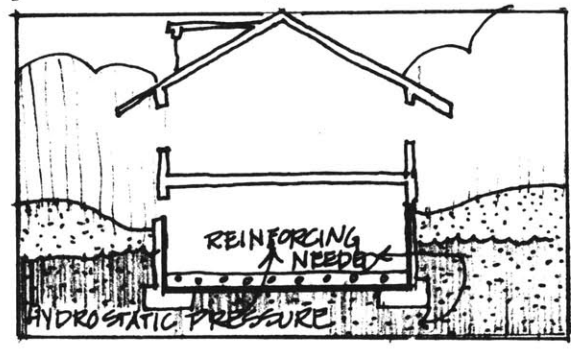
o BUILDING THROUGH THE WATER TABLE REQUIRES HEAVY CONSTRUCTION AND WATERPROOFING, TO COUNTER THE CONSTANTLY WET CONDITIONS AND THE HYDROSTATIC PRESSURE OF .433 PSI/SQ.FT. IF IT IS ABSOLUTELY NECESSARY TO BUILD BELOW THE SURFACE OF THE WATER TABLE, DUE TO A VERY HIGH WATER TABLE OR THE NEED FOR ADDITIONAL SUBGRADE FLOORS, SEVERAL PROBLEMS MUST THEN BE ADDRESSED:

A HIGH WATER TABLE

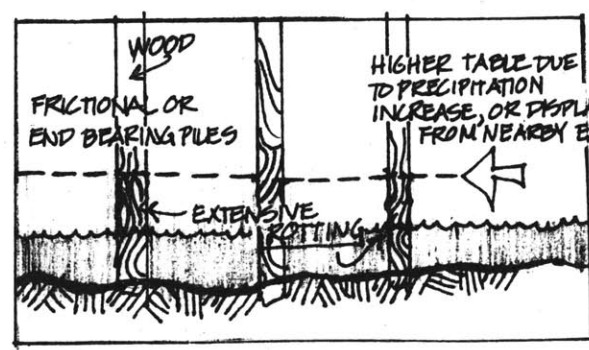
A high water table causes difficulties in excavation work. When the table is less than 6-8 feet below the surface, all development costs are increased: excavations must be braced with sheeting, and pumped out; and utilities and basements must be waterproofed thoroughly against seepage. Cellars which sit below the water table require the careful placing of drainage channels and membrane waterproofing. Corrosion and freezing is the last consequence of high water tables, since the water involved is often chemically corrosive, and also subject to expansion and contraction with temperature changes.



Additionally, wet soils exert a far greater pressure on building foundations than drained soils. In wet soils, it may be necessary to reinforce the floor heavily to prevent upward explosion. In short, one must effectively design a boat hull for construction below the table, since damprooting alone will not resist hydrostatic pressures.



A FLUCTUATING WATER TABLE:



A fluctuating water table (due to precipitation conditions, or nearby construction) poses several problems:

- 1) ground settlement with the lowering of the water table;
- 2) ground heaving with a climbing table;
- and 3) the rotting of those materials which can handle either wet subsoil conditions or dry, but not both. This is especially apparent in old buildings on wooden piles, where the fall of the table erodes the saturated wood.

references: 4, 7, 13, 21

The Water Table:

17

Topography

Topography & Insolation

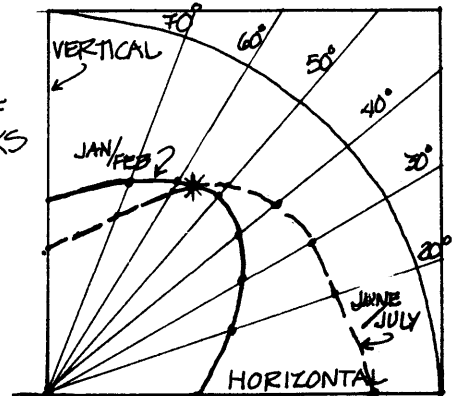
IN SELECTING ADVANTAGEOUS SITING LOCATIONS, SEEK OR DESIGN SLOPES WHICH RECEIVE LARGE AMOUNTS OF RADIATION DURING UNDERHEATED MONTHS AND LESS RADIATION DURING OVERHEATED MONTHS.

THE MAJOR REASONS FOR MAXIMIZING RADIATION DURING THE WINTER SEASON INCLUDE: FOR HEATING THE ATMOSPHERE AND PREVENTING COLD, SHADOW AREAS; FOR HEATING THE GROUND TO PROVIDE NIGHT TIME RERADIATION; FOR REFLECTING RADIATION INTO COLDER SPACES. AND FINALLY, FOR HEAT COLLECTION IN SOLAR PANELS AS AN ENERGY SOURCE. HOWEVER, MAXIMIZING SOLAR HEAT GAIN IN THIS WINTRY CLIMATE DOES NOT HAVE TO CONFLICT WITH MINIMIZING THE HEAT GAIN DURING THE SUMMER MONTHS. NOT ONLY CAN COMPROMISE ORIENTATIONS AND INCLINATIONS BE FOUND, BUT VEGETATION, AWNINGS OR INDUCED WIND MOVEMENT CAN FURTHER REDUCE THE SUMMER HEAT GAIN.

TO COMPUTE THE QUANTITY OF RADIATION THAT WILL FALL ON A SURFACE, ONE NEEDS TO KNOW: 1) THE GEOGRAPHIC LATITUDE, 2) THE DECLINATION OF THE SUN (TIME OF YEAR), 3) THE ALTITUDE OF THE SUN (TIME OF DAY), 4) THE ANGLE OF THE SLOPE, AND 5) THE DIRECTION IT FACES. RULES OF THUMB FOR THESE LAST TWO VARIABLES - ORIENTATION AND INCLINATION - BECOME CRUCIAL FOR SOLAR PANEL DESIGN. HOWEVER, THIS CAN BE JUST AS SIGNIFICANT, IF NOT MORE SO, IN SITE DESIGN.

INCLINATION

IT IS SURPRISING THAT IN WINTER, AN INCLINED SURFACE CAN RECEIVE AS MUCH AS THREE TIMES THE RADIATION OF A HORIZONTAL SURFACE. EVEN 10° SLOPES ARE TWO WEEKS AHEAD IN THE ARRIVAL OF SPRING, RECEIVING TWICE AS MUCH RADIATION IN WINTER. WHAT IS WORSE IS THAT THE COMMON, HORIZONTAL SITE, RECEIVING LESS IN WINTER, ALSO RECEIVES AN UNDESIRABLE MAXIMUM IN SUMMER. AS A GENERAL RULE, THE IDEAL INCLINATION FOR MAXIMUM SUN EXPOSURE IN WINTER IS THE DEGREE LATITUDE $+15^\circ$, WHILE IN SUMMER, MAXIMUM EXPOSURE OCCURS AT THE DEGREE LATITUDE -15° OR MORE.

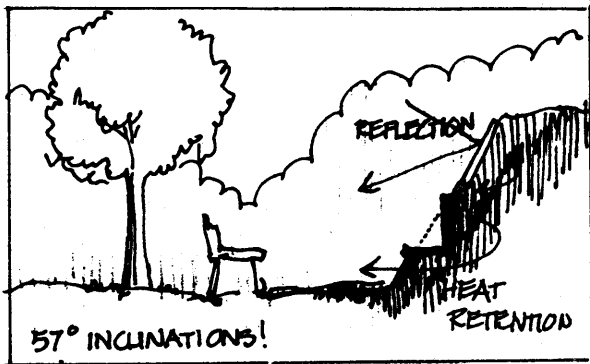


(40N) INSOLATION VALUES FOR DIFF. INCLINATION

ORIENTATION

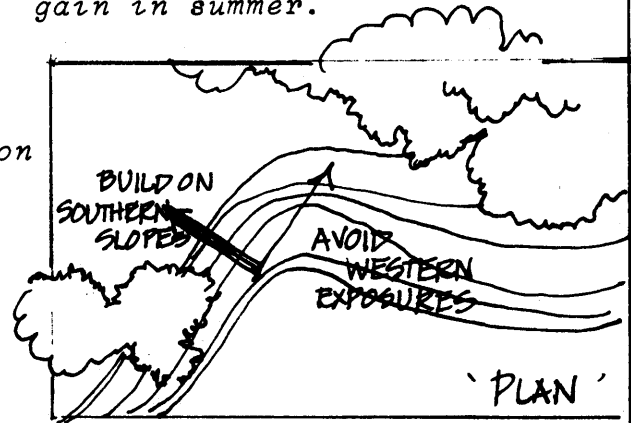
ONCE THE ANGLE OF THE SLOPE HAS BEEN DETERMINED FOR MAXIMUM OR MINIMUM EXPOSURE DEPENDING ON THE TIME OF YEAR, THE DIRECTION OF THE SLOPE ALSO NEEDS TO BE DETERMINED. AS A RULE OF THUMB, SOUTH FACING SLOPES USUALLY PROVIDE THE BEST INSOLATION CONDITIONS, WITH GOOD SOLAR HEAT GAIN IN WINTER AND MUCH LESS SEVERE HEAT GAIN IN SUMMER. THEN, AVOID WESTERN AND EASTERN EXPOSURES, SINCE MAXIMUM HEAT GAIN IS NOW, ADVERSELY, IN SUMMER INSTEAD OF WINTER. HOWEVER, WHEN SITE SELECTION OR BUILDING PLACEMENT IS RESTRICTED TO EAST OR WEST FACING SLOPES, KEEP IN MIND THAT MORNINGS ARE COOLER (DUE TO LOW EVENING TEMPERATURES) WHILE THE AFTERNOON IS WARMER - ALWAYS GIVING PREFERENCE TO EAST OR SOUTHEAST EXPOSURES OVER WEST AND SOUTHWEST. FINALLY, FLATTENED SITES SHOULD BE AVOIDED, SINCE HORIZONTAL SURFACES SECURE THE SMALLEST HEAT GAIN IN WINTER, BUT UNDESIRABLY THE MOST HEAT GAIN IN SUMMER.

DESIGN IMPLICATIONS



Although a 67 degree slope is much too steep for a building site, it can be useful in the design of retaining walls, to define parks, or in deciding roof and wall pitch. Avoiding flat sites, or grading to provide some degree of slope, could double heat gain in winter months and halve heat gain in summer.

If south-facing slopes are available, by all means build there. A north orientation will cause excessive heating bills in winter, receiving no help from the sun. In addition, a west orientation will receive excessive glare and overheating in summer, putting undue stress on normally unnecessary air conditioning.



KNOWING THESE PRINCIPLES AN ARCHITECT CAN SELECT A SITE SUITING THE INSOLATION NEEDS, AND SELECT SUITABLE SLOPES FOR ROOFS, WALLS AND BUILT GROUND SURFACES ACCORDING TO WHETHER MORE OR LESS (ABSORBED OR REFLECTED) SOLAR HEAT IS DESIRED AT A GIVEN TIME.

	N	NE	E	SE	S	SW	W	NW	HORIZ
JAN/FEB	2	2.5	8.5	18	25	18	8.5	2.5	1.5
JUNE/JUL	8	16	23	20	14	20	23	16	42
YEAR TOTALS	51	98	184	243	252	243	184	98	312
HEATING SEASON	30	52	116	128	204	178	116	52	191
COOLING SEASON	22	46	67	64	47	64	67	45	121

SOLAR HEAT GAIN FACTOR
X 1000 BTU/FT²
ON A VERTICAL FACE.

references: 1, 7, 15, OTHERS

Topography & Insolation

Topography & Temperature:

CLUES

- LOCATE AREAS IN SUN-SHADOW WITHIN THE SITE, AS CAUSED BY PROMINANT TOPOGRAPHIC FORMS.
- AREAS WHICH ARE BLESSED WITH PROTECTION FROM WINDS, IN WIND SHADOW, AND BENEFIT OF ADEQUATE SUNSHINE, WILL BE CLOTHED IN PROFUSE VEGETATION, EXCEPT WHEN THIS RESULTS IN OVERHEATING.

	ΔT
LAKE FRONT	3.1°F
HIGH BUILDING	3.8°F
SMALL VALLEY	8.2°F
TOP OF SLOPE	14.2°F
SMALL VALLEY (HIGHER ALT.)	20°F
SOUTH EDGE OF LARGE VALLEY	15°F
BOTTOM OF LARGE VALLEY	20.2°F

- THE DESIGN TEMPERATURES IN RELATION TO DIFFERENT TOPOGRAPHIES, SHOULD BE DETERMINED BY THE AMOUNT OF TEMPERATURE CHANGE FROM DAY TO NIGHT, WHICH MUST BE DEALT WITH.

GENERAL INFORMATION

TEMPERATURE & HEIGHT

AT A VERY LARGE SCALE, THE TEMPERATURE OF AIR DECREASES WITH ALTITUDE; AT A RATE OF 10°F FOR EACH 330 FOOT RISE IN SUMMER AND EACH 400 FOOT RISE IN WINTER. AT A LOCAL SCALE, THE TEMPERATURES OVERLYING A SITE ARE DETERMINED BY THE RISES AND FALLS IN THE TERRAIN. ON FLAT SURFACES, THE COLD AIR WILL GRIP THE GROUND, WHILE ON SLOPING SURFACES THERE IS A TENDENCY FOR THE HEAVIER COLD AIR TO SLIDE TO THE LOWEST PLACE IT CAN FIND. AS A RESULT, CONCAVE FORMS IN THE TERRAIN ARE USUALLY MUCH COLDER AT NIGHT IN RELATION TO THE SURROUNDINGS. (CAUTION MUST BE TAKEN, HOWEVER, IN THINKING COLD AIR BEHAVES LIKE WATER. AIR CAN HUG THE SURFACE OF THE GROUND AND BUILD UP WHILE THERE ARE STILL LOWER PLACES NEARBY, PROTECTED BY EDDIES.

TOPOGRAPHY & HEAT CAPACITY

THE HEATING CAPACITY OF A PARTICULAR TOPOGRAPHY IS MAINLY DETERMINED BY THE ORIENTATION AND INCLINATION OF THE SLOPES (PG.), ALONG WITH THE SOIL TYPE. THE PROPER PLACEMENT AND GRADING OF SLOPES, HOWEVER, CAN INSURE MAXIMUM EXPOSURE TO THE SUN'S HEAT, WHICH IF RETAINED FOR LONG PERIODS WILL STABILIZE TEMPERATURES. IN ADDITION, GROUND BERMS PILED AGAINST OR NEAR A BUILDING, CAN BE VERY EFFECTIVE INSULATORS, (MAINTAINING A STEADY TEMPERATURE OF 55°) AS WELL AS PROTECTING THE BUILDING WALL FROM THE WIND AND RAPID THERMAL EXCHANGE.

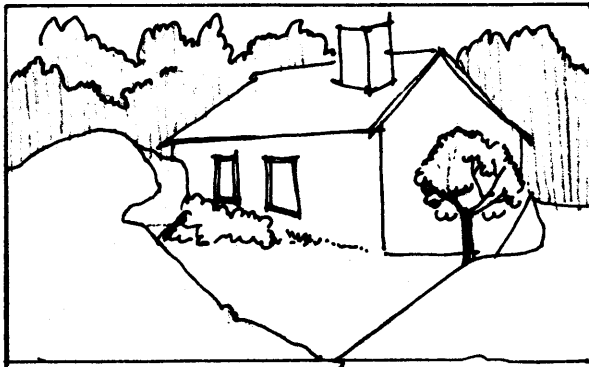
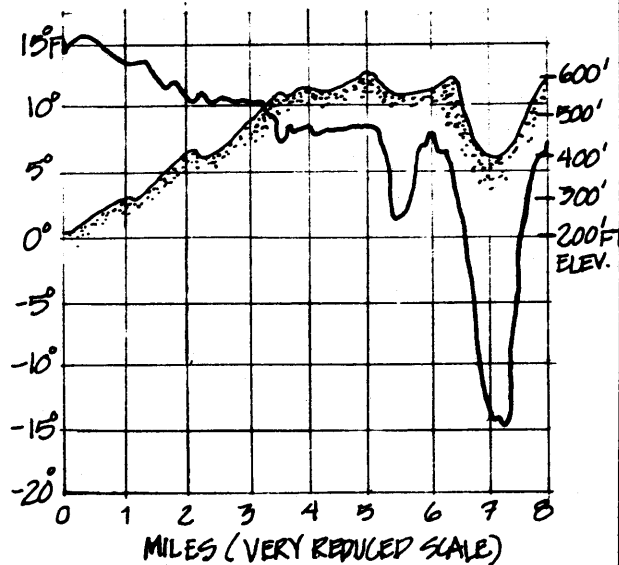
TOPOGRAPHY - SUN AND WIND SHADOWS

SUN SHADOWS: ALTHOUGH SUN EXPOSURE CAN RAISE THE TEMPERATURE OF AN AREA QUICKLY, THE SHADOWS CAST BY DIFFERENT LANDFORMS ARE ALSO SIGNIFICANT IN DETERMINING THE TEMPERATURE OF THE SITE. THE HIGHER SIDES OF SLOPES WHICH RECEIVE MAXIMUM SUNLIGHT, OFTEN SHADE OR PREVENT SITES BEHIND FROM RECEIVING WINTER SUN WHEN IT IS NEEDED MOST. RESULTING TEMPERATURES ARE OFTEN 5-10° LOWER.

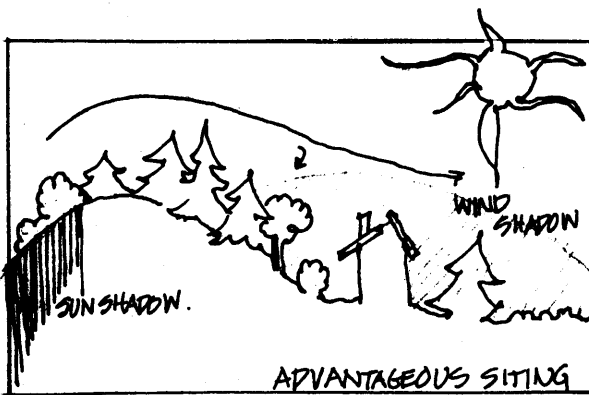
WIND SHADOWS: THE LEEWARD SIDE OF SLOPES, AND LOW AREAS ARE MORE PROTECTED FROM THE WINDS, REDUCING HEAT EXCHANGE AND HEAT LOSS. THEREFORE, AREAS IN SHIELDED 'WIND SHADOWS, BEHIND HILLS OR SLOPES, ARE OFTEN MUCH WARMER AND MORE SUITED FOR BUILDING.

DESIGN IMPLICATIONS

The presence of lower local temperatures, can often be predicted by identifying areas in the topography of: low sun exposure, extreme altitudes, and high wind exposure; or identifying areas of local depressions, which pool or dam the slipping cold air.



By redistributing the cut and fill of a site into ground berms, against or near a building, a windowless wall can gain a steady-temperature insulator, offering protection from the wind and from rapid thermal exchange.



In analyzing the site topography, recognize the existing or designed areas that are in sun shadow due to the terrain. Also recognize areas protected within a wind shadow which will result in warmer local temperatures (due to reduced heat exchange). Ideally, south-facing slopes receive maximum sunlight, as well as being protected from northern winter winds and open to summer cooling winds.

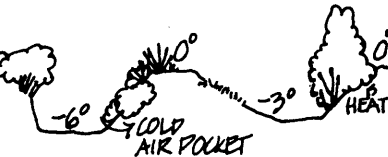
references: 4, 5, 9, 10

Topography & Airflow:

CLUES



- THE LACK OF VEGETATION ON A SITE, WILL POINT



OUT AREAS WHERE COLD AIR HAS POOLED OR DAMMED UP. ON THE OTHER HAND, SLOES WHICH ACT AS LONG THERMAL RESEVOIRS WILL ENABLE VEGETATION TO FLOURISH WITH PROTECTIVE EDDIES.

- THE PRESENCE OF FROST ALSO INDICATES AREAS WHERE COLD AIR HAS BEEN TRAPPED, WITHOUT MEANS OF ESCAPE.

GENERAL INFORMATION

NATURAL AIR FLOWS:

INGENERAL, WHEN THERE ARE NO OBVIOUS WINDS EXISTING, AIR MOVEMENT IS CAUSED BY THE NATURAL FLOW OF COLD AIR, ALONG THE LINE OF LEAST RESISTANCE, TO THE LOWEST POINT. THUS, IN A VALLEY, OR A DIP IN THE TOPOGRAPHY, OR AT THE FOOT OF A LONG SLOPE, THE AIR IS TYPICALLY COOLER AND DAMPER WITH GREATER FROST OCCURENCES. THEN, THE INFLUENCE OF TOPOGRAPHY ON THIS AIR FLOW IS OFTEN MORE NOTICEABLE DURING THE DAY THAN AT NIGHT. THE DIFFERING AMOUNTS OF HEAT RECEIVED BY SLOPES OF DIFFERENT INCLINATIONS AND ORIENTATIONS, WARM THE LAND IN CERTAIN SPOTS MORE THAN OTHERS. THE RESULTING DIFFERENCES IN TEMPERATURES GIVE RISE TO UNEQUAL PRESSURES, CAUSING LOCAL EDDIES WITH THE FLOW OF COOLER AIR CURRENTS TO THE WARMER SLOPES.

AT NIGHT, THE ORIENTATION OF THE SLOPE IS LESS IMPORTANT, AND THEN IT IS THE THERMAL CAPACITY OF THE DIFFERENT SURFACES WHICH RULES. NORMALLY, THE EARTH RETAINS HEAT LONGER THAN AIR, SO THAT THE WARM AIR NEAR THE GROUND SURFACE AT NIGHT, CONTINUALLY RISES TO BE REPLACED BY COOLER AIR. AS A RESULT, COLD AIR FLOODING IS COMMON ON OPEN SLOPES, ESPECIALLY AT NIGHT (AND ON COLD SUNLESS DAYS WHEN THE GROUND HAS MAINTAINED THE HIGHER TEMPERATURES) AND MUST BE PREVENTED FOR COMFORTABLE DESIGN CONDITIONS.

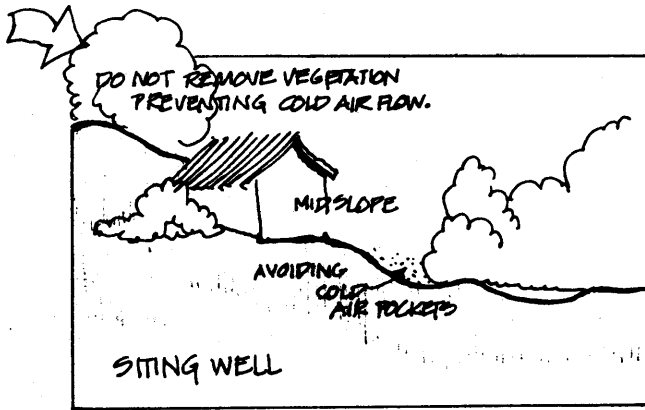
INDUCED AIR FLOWS:

1) OBSTACLES: SINCE COLD AIR FLOWS DOWNWARD, FOLLOWING THE LINE OF LEAST RESISTANCE, IT IS READILY DIVERTED BY OBSTACLES SUCH AS WALLS OR TREES. THESE BARRIERS SHOULD BE PLACED TO CONCENTRATE THE AIR FLOW INTO WELL-DEFINED CHANNELS, TO PROTECT THE BUILDING AND SITE FROM DRAFTS.

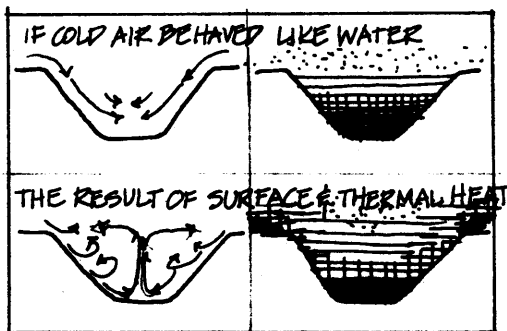
2) GRADING: BESIDES THE USE OF HEDGES, WALLS, AND FOREST BELTS, GRADING BY FILLING HOLLOW, AND CREATING SHELTERED AREAS, CAN ALSO PREVENT A ZONE OF COLD AIR CURRENTS. IN EVERYCASE, COLD AIR CURRENTS SHOULD NOT JUST BE 'DAMMED' BUT PROVIDED WITH AN ALTERNATE MEANS TO FLOW DOWNWARD AND STILL AVOID THE BUILDING SITE.

3) MATERIALS: FINALLY, A CHANGE IN GROUND MATERIALS CAN INDUCE OR PREVENT BREEZES AS NECESSARY FOR THE MOST COMFORTABLE ENVIRONMENT. THE SURFACE AND THERMAL DIFFERENCES OF LAND AND WATER, FOR INSTANCE, CAN SET UP SHORE BREEZES. DURING THE DAY THE WARMER LAND AIR RISES, RESULTING IN A FLOW OF COOLER SURFACE AIR FROM THE SEA. AT NIGHT, WATER - WITH ITS LONG RANGE THERMAL CAPACITY IS WARMER, SO ITS RISING COLUMN OF WARM AIR IS REPLACED BY (10°) COOLER BREEZES OFF THE LAND.

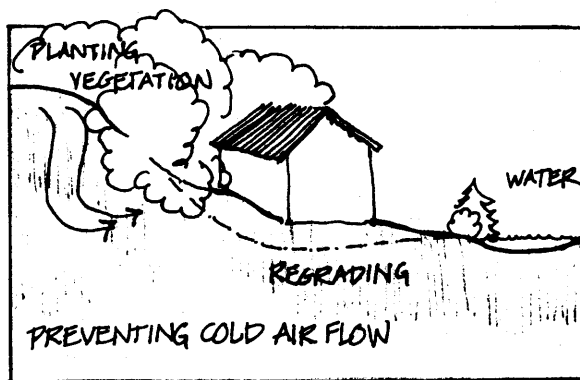
DESIGN IMPLICATIONS



First of all, site the buildings well. For design purposes, the best local wind conditions will be: on upper or middle slopes rather than at the foot, or at the crest (where cold air dams); on the slopes facing south or southeast for maximum sun advantage; and lastly located near water for its long-range heat retaining capacity.



In general, the site selected should not lie in the zone of cold air currents. However, if this siting is unavoidable, cold air currents can be cut off by hedges or forest belts at higher levels (always providing an alternate means for the cold air flow). Regrading is also effective for redirecting cold air flows or for eliminating cold air pockets. Finally, place and mix your materials well. The induced breezes from heat-retaining materials-especially water- will help stabilize air temperatures from day to night. Then, reflective (e.g. asphalt) surfaces will induce off shore breezes during the day, which must be blocked or welcomed as needed for seasonal comfort.



references: 5, 6, 7, 8,

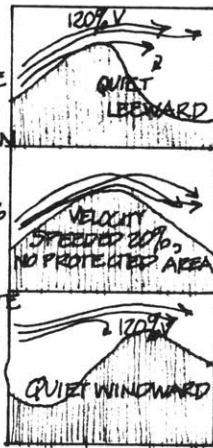
Topography & Airflow:

Topography & Wind Movement

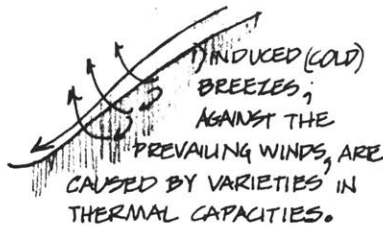
CLUES

◦ RECOGNIZE THE DIRECTIONS AND VELOCITIES OF THE PREVAILING WINDS, AND WHEN THEY CAN BE BENEFICIAL FOR CREATING A COMFORTABLE SITE.

◦ RECOGNIZE THE WAY IN WHICH THE EXISTING TOPOGRAPHY & VEGETATION AFFECT THESE PREVAILING WINDS, TO CREATE THE LOCAL CONDITIONS. IF THE SITE CLIMATE IS DESIRABLE, BE WAARY OF CHANGING EITHER THE TOPOGRAPHY OR THE VEGETATION.



◦ THE EFFECT OF LOCAL EDDIES ON THE DIRECTION OF THE PREVAILING WINDS ARE HARD TO PREDICT, BUT CAN BE MEASURED ON THE SITE, BEFORE DESIGNING.



2) EXISTING SLOPES AND WINDBREAKS COULD WELL BE PROVIDING THE PROTECTION FOR DESIRED AREAS AND VEGETATION.

GENERAL INFORMATION

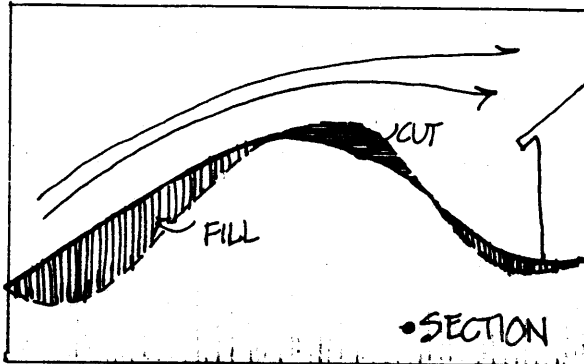
IN ADDITION TO AFFECTING THE AMOUNTS OF INSOLATION RECEIVED, THE LOCAL AIR CURRENTS AND TEMPERATURES, TOPOGRAPHY CAN AFFECT REGIONAL WIND MOVEMENT AS WELL.

PREVAILING WIND SPEEDS ON THE CREST OF A RIDGE MAY BE 20% GREATER THAN ON FLAT GROUND. HIGHER WIND SPEEDS CAUSE DRYNESS AND COLDNESS, USUALLY WHERE UNWANTED, BUT CAN BE USEFUL IN COOLING AREAS ON HOT DAYS. THE GENERAL RULE FOR EVALUATING THE EFFECT OF LOCAL TOPOGRAPHY ON WIND MOVEMENT IS THAT WIND WILL BE MUCH QUIETER ON THE LEE SIDE (THAN ON THE WINDWARD SIDE) OF ANY RISE IN THE TERRAIN. THIS CONDITION CAN BE REVERSED, HOWEVER, IF THE LEE SLOPE IS GENTLE, WHILE THE WIND SIDE IS VERY STEEP. SO, BY PROPER BUILDING PLACEMENT OR REGRADING, WINDS CAN BE CHANNLED AND HURRIED TO COOL AND DRY AREAS, OR DETOURED TO PROVIDE PROTECTED AREAS AND LESS EROSION.

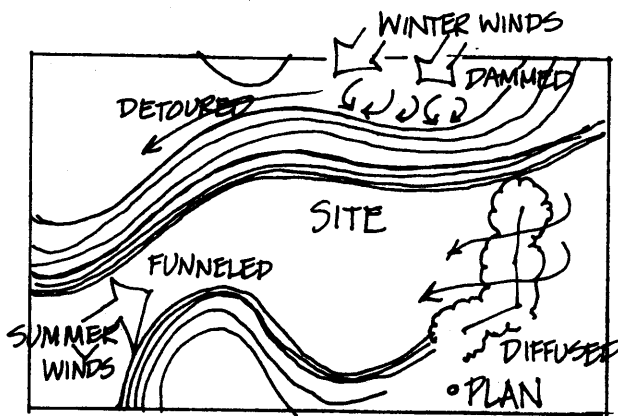
LOCALIZED CONDITIONS: REGIONAL WIND DIRECTIONS USUALLY DOMINATE ON ANY SITE, UNLESS THEY HAVE BEEN REDIRECTED COMPLETELY LEAVING A SITE TO ITS OWN LOCAL AIR FLOW. HOWEVER, REGIONAL WIND DIRECTIONS CAN BE REVERSED OR ALTERED SLIGHTLY BY STRONG UPSLOPE AND DOWN SLOPE WINDS. THESE WINDS ARE ACTUALLY VERY STRONG AIR FLOW MOVEMENTS CAUSED BY THERMODYNAMIC EXCHANGE. IN EFFECT, HEATED SLOPES, DUE TO MAXIMUM EXPOSURE, WARM THE AIR, INDUCING COLD AIR FRONTS TO SWEEP IN AND SOMETIMES REVERSE THE REGIONAL WIND CONDITIONS. ALTHOUGH THESE CONDITIONS ARE ALMOST IMPOSSIBLE TO DESIGN FOR, THEY ARE MEASURABLE TO ESTABLISH DESIGN GIVENS.

WIND MANAGEMENT: WINDBREAKS WIND MANAGEMENT NOT ONLY IMPLIES STOPPING THE WIND, BUT ALSO REDIRECTING, SLOWING, AND SPEEDING WIND VELOCITIES. ON HILLY SLOPES, OR WHERE EXTENSIVE GRADING IS NEEDED, A WINDBREAK CAN BE FORMED BY PILING THE EARTH TO MAKE A PROTECTING RIDGE. RIGHT ANGLE ORIENTATION TO THE OBJECTIONABLE WIND IS BEST FOR STRAIGHT, EXTENDED WINDBREAKS; AND THEN, ALLOWING FOR A MINIMAL PASSAGE OF AIR THROUGH, WILL REDUCE EDDIES ON THE OTHER SIDE.

DESIGN IMPLICATIONS



If local topographic conditions cause undesirable winds, then the process of cut and fill can create a more comfortable wind flow, reducing dryness, coldness, and wind erosion.



This regrading for better site climates, however, must be done in plan as well as in section. The wind can be 1) funneled for use, 2) dammed (with eventual overflow), 3) diffused, 4) detoured; or all four as useful in different areas of the site.

In general, a living windbreak can look more natural and can provide seasonal change of vegetation. However, they require far more lateral space than a constructed fence. As one example of ideal wind management, an elongated clearing should be oriented with the partially open end towards the approach of the prevailing wind in summer, with the width of the opening set relative to the funneling effect required.

references:
2, 5, 6, 9, 14

: Topography & Wind Movement :

Topography & Water Conditions:

CLUES

° DRAINAGE CONDITIONS ON A SITE CAN BE QUICKLY READ THROUGH THE VEGETATION PRESENT (SEE VEGETATION: PG.). THIS IS ESPECIALLY TRUE FOR AREAS OF NO DRAINAGE WITH SWAMP VEGETATION, AND AREAS OF HIGH EROSION WITH NO VEGETATION AT ALL. EVALUATION MUST THEN BE MADE TO DETERMINE WHETHER IT IS THE EXISTING TOPOGRAPHY, WHICH CAUSES THESE UNWANTED CONDITIONS, THUS REQUIRING A GRADING CHANGE.



° AREAS WHERE MOISTURE IS RETAINED, PRECIPITATION IS ADEQUATE, AND WIND AND SUN CONDITIONS ARE NOT SEVERE ARE EASILY RECOGNIZED BY THE FLOURISH OF RICHER, DENSER VEGETATION.

GENERAL INFORMATION

TOPOGRAPHY AND DRAINAGE

SLOPES OVER 50 OR 60 PERCENT CANNOT BE PROTECTED FROM EROSION (EXCEPT BY TERRACING OR EMBEDDED REINFORCEMENT). AS A GOOD STANDARD, GRASS - WHICH ONLY REQUIRES A SMALL AMOUNT OF SEEPAGE FOR SURVIVAL - WILL NOT USUALLY GROW ON SLOPES GREATER THAN 25%. IN GENERAL, THE STEEPER THE LAND, THE MORE LIKELY THAT RUNOFF WILL OCCUR, INSTEAD OF THE NEEDED SEEPAGE.

ON THE OTHER HAND, SLOPES UNDER ONE PER CENT DO NOT DRAIN WELL. CONCAVE HOLLOW IN THE TERRAIN, OR NON-POROUS AREAS AT THE FOOT OF HILLS AND SLOPES OR ON LEVELED SITES, WILL OFTEN BE WET WITH VERY POOR DRAINAGE. THEN, THE ACCUMULATION OF RUNOFF FROM MANS' SLOPED ROOFS AND ASPHALTED SURFACES, THE REMOVAL OF HEAVY-DRINKING VEGETATION, AND THE POOLING OF WATER NEAR NON-POROUS FOUNDATION WALLS, WILL INCREASE THE OCCURENCES OF THESE WET SPOTS. SO, NOT ONLY IS THE SLOPE OF THE LAND VERY IMPORTANT IN THE POTENTIAL DRAINAGE OF THE SITE, BUT SO ARE THE ADDED DIMENSIONS AND MATERIALS PROVIDED BY VEGETATION, BUILT SURFACES, AND SITE REDISTRIBUTION.

TOPOGRAPHY AND MOISTURE

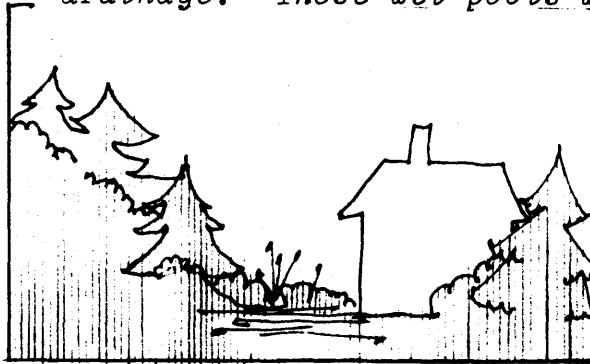
THE MOISTURE OF A SITE IS MOSTLY A CONSEQUENCE OF ITS PRECIPITATION, VEGETATION AND SOIL DRAINAGE. HOWEVER, THE PRESENCE OF CERTAIN TOPOGRAPHIC FORMS WILL AFFECT THIS. SLOPES WHICH ARE ORIENTED FACING THE SUN, OR FACING HEAVY WINDS, ARE CONTINUALLY SUBJECT TO EVAPORATIVE DRYING, WHICH THEN REDUCES SITE MOISTURE SIGNIFICANTLY.

TOPOGRAPHY AND PRECIPITATION

WHEN A LAYER OF AIR IS DEFLECTED UPWARDS ON THE WINDWARD SIDE OF A LARGE MOUNTAIN, IT IS SUBJECT TO COOLING. IF THIS AREA WAS IN FULL SUN, AND ON A HUMID SLOPE, IT MAY THEN BE FORCED TO RELEASE RAIN, BECAUSE AT THE LOWER TEMPERATURES IT CANNOT HOLD AS MUCH WATER VAPOR AS IT COULD WHEN WARM. CONSEQUENTLY, THE WINDWARD SIDE OF SLOPES AND RANGES ARE OFTEN PLAGUED WITH HEAVIER PRECIPITATION, WHILE THE LEEWARD SIDES ARE DRY. IN ADDITION, THE WINDWARD SIDES AT THE SUMMITS OF HILLS HAVE A GREATER TENDENCY TO ATTRACT CLOUDS.

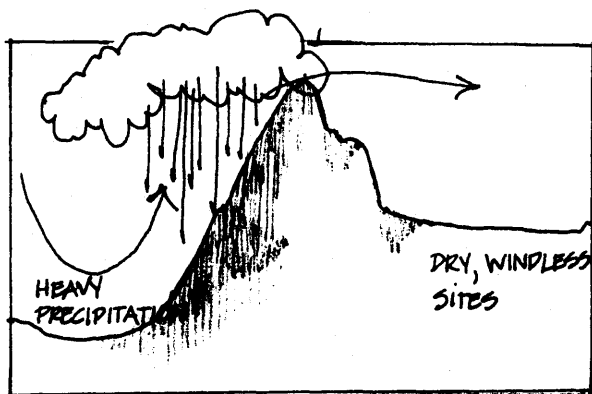
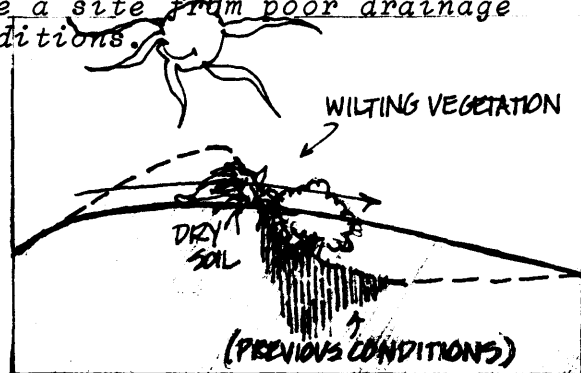
DESIGN IMPLICATIONS

Areas at the base of slopes, on completely leveled sites and in dips in the terrain, are often very wet with poor drainage. These wet pools will undermine foundation



stability, corrode basement materials and then leave a wet, colder basement as a stamp. Learn to recognize well drained sites and whether it is the topography (steep, moderate, or flat) which is allowing for the idealized drainage conditions. If so, unthinking topography changes could well disrupt the natural drainage channels, causing gullies and erosion elsewhere. Hesitation before bulldozing, as well as careful grading, can save a site from poor drainage conditions.

Avoid changes in topography which will allow exposure to the scorching sun or passage to the drying wind, since this will speed evaporation of the needed moisture in a site.



Recognize the modifications in the regional precipitation givens, caused by ridges and peaks which force the air to release rain unexpectedly by rapid cooling. The result is often sites plagued by dryness or unexpected quantities of rainfall.

references: 5, 7, 13, 21

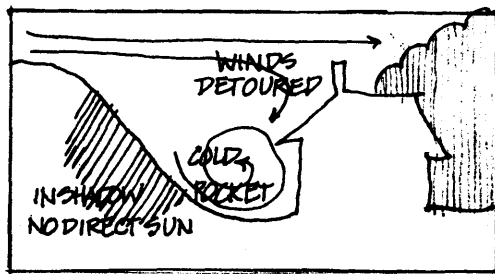
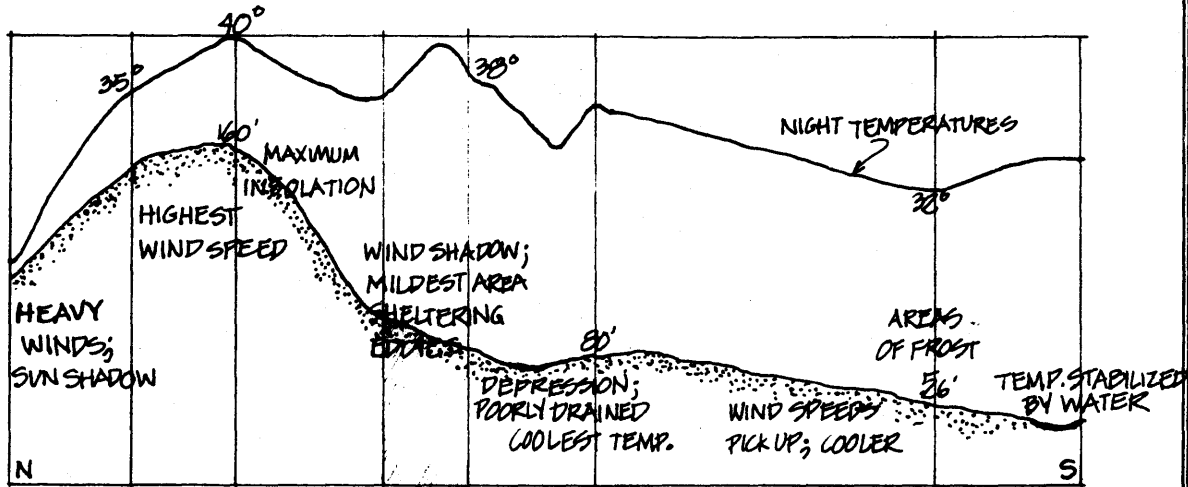
—: Topography & Water Conditions:

Topography

THE ACTUAL DESIGN OF SLOPES AND GROUND-FORM COMES WITH THE CONSIDERATION OF ALL OF THESE ISSUES: INSOLATION, TEMPERATURE, WATER CONDITIONS, AIR FLOW, AND WIND MOVEMENT.

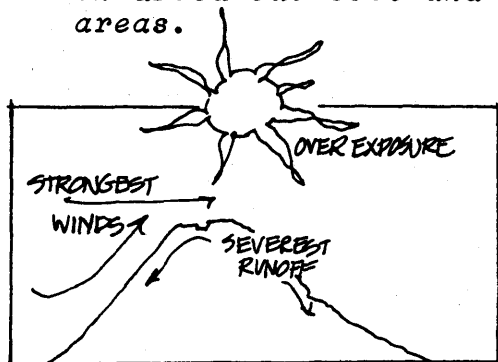
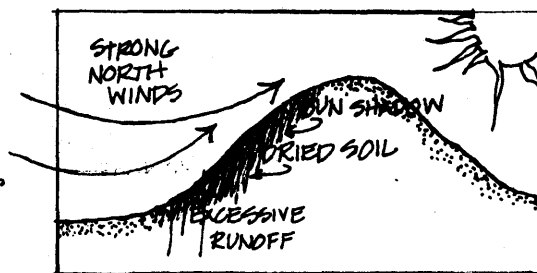
Microclimate :

... IN SHORT, EVALUATION OF THE MICROCLIMATE EXISTING & DESIRED.



Lowest areas are often the coldest, especially at night, since cold air runs downhill and collects in frost pockets created by buildings. With poor orientation, these areas could also be in the shadow of the hill. All this leads to costly heating.

In addition to receiving less sunlight, the north slope feels the full force of winter winds, resulting in dried out soil and colder areas.



Crests receive all the elements in full strength, often subject to great variability in climates, with few of the attributes that come with being hidden.

ref: 5, 8, 17

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Soils.

Soil Identification:

CLUES

WAYS OF VISUALLY IDENTIFYING THE DIFFERENT SOILS INCLUDE:

SANDY SOIL WILL HAVE NO SURFACE WATER, BE SHIFTY, AND USUALLY DRY.

SILT SOIL CAKES IN A POWDERY FASHION AFTER RAINS.

CLAYEY SOIL CRACKS WHEN DRY, ACTS AS ONE MASS, WITH WATER BEADING ABOVE.

THE INTRODUCTION OF ORGANIC MATTER INTO THESE SOILS CAN OFTEN BE RECOGNIZED BY DARKER, RICHER BROWNS, AND A SPONGY FEELING.

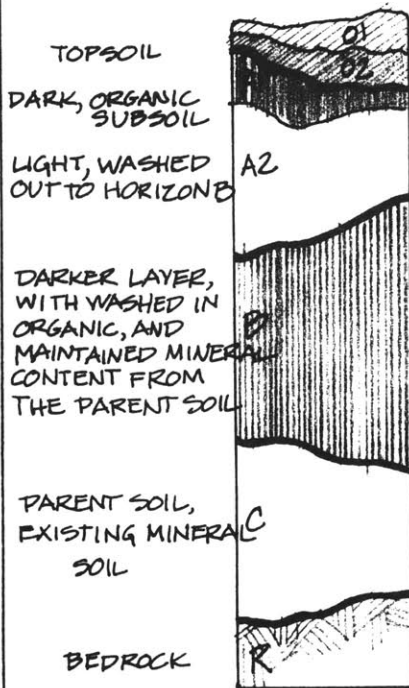
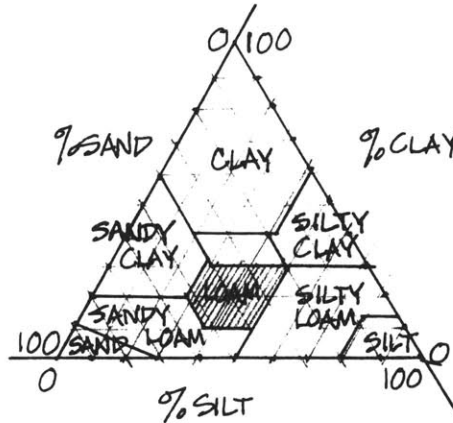
GENERAL INFORMATION

SOIL IS AN AGGREGATE OF FOUR MAJOR COMPONENTS: MINERAL GRAINS 45%, ORGANIC GRAINS 5%, WATER 25%, AIR 25%.

SOILS ARE CLASSIFIED BY THE SIZE OF THE MINERAL GRAINS:

- GRAVEL 2MM → DIAMETER PARTICLES
- SAND .05MM → 2MM PARTICLES (GRITTY, JUST VISIBLE)
- SILT .002MM → .05MM PARTICLES (SMOOTH, NOT VISIBLE)
- CLAY UNDER .002MM (FLOURY DRY, PLASTIC WET)

THE COMBINATION OF THESE PARTICLES, THEN, DESCRIBE THE WHOLE RANGE OF SOIL TYPES.



THIS MINERAL-GRAIN CLASSIFICATION MUST SUBSEQUENTLY BE MODIFIED BY THE INTRODUCTION OF THE ORGANIC CONTENT. THIS RESULTS IN STRATIFIED CLASSIFICATIONS OF SOILS INTO HORIZONS.

BROADLY SPEAKING, ALL SOIL PROFILES CONTAIN TWO OR MORE HORIZONS, OR LAYERS. THE 'O' HORIZON INCLUDES O1) DOMINATED BY FRESH UNDECOMPOSED ORGANIC DEBRIS SUCH AS LEAVES, AND O2) DOMINATED BY FRESH AND PARTLY DECOMPOSED ORGANIC MATERIAL - MORE THAN 30% IN CLAYEY SOILS, MORE THAN 20% IN SILTY OR SANDY SOILS. THE 'A' HORIZON IS THE FIRST MINERAL HORIZON AND CONSISTS OF A1) A DARK LAYER WHERE A HIGH PROPORTION OF FINELY DIVIDED ORGANIC MATTER HAS ACCUMULATED, AND A2) A LIGHT COLORED LAYER WHERE ORGANIC MATTER HAS BEEN WASHED OUT TO HORIZON 'B'. THE 'B' HORIZON IS AN ILLUVIAL (WASHED IN) CONCENTRATION OF ORGANIC MATTER FROM HORIZON 'A', AND MINERAL MATTER FROM THE PARENT SOIL - HORIZON 'C'.

DESIGN IMPLICATIONS 25

IDENTIFYING SOILS ON A VARIABLE SITE WITHOUT AN EXPERT CAN BE DIFFICULT; HOWEVER, ACCURATE IDENTIFICATION BRINGS A WEALTH OF INFORMATION FOR RESPONSIVE BUILDING...

SOIL IDENTIFICATION

SAND OR GRAVEL? DRY A HANDFUL OF SOIL:

- IF PARTICLES ARE VISIBLE = SAND OR GRAVEL
- IF ONE-HALF THE PARTICLES $> \frac{1}{4}$ " = GRAVEL
- IF LESS THAN 10% IS INVISIBLE = CLEAN SAND/G.
- IF NOT, IT IS A SILTY OR CLAYEY SAND OR GRAVEL

CLAY OR SILT? WEED OUT COARSER PARTICLES, AND WET SOIL AND MOLD IT INTO A PAT-LET DRY, TRY TO BREAK IT BY THUMB PRESSURE:

- IF IT CANNOT BE BROKEN OR POWDERED, BUT ONLY SNAPS WITH GREAT EFFORT = PLASTIC CLAY
- IF IT IS BROKEN WITH SOME EFFORT = ORGANIC CLAY
- IF IT IS BROKEN AND POWDERED EASILY = SILT

PLASTIC OR NON-PLASTIC?

- IF IT CAN BE MOLDED AND REMOLDED WHEN SLIGHTLY DAMP = PLASTIC CLAY
- IF IT REMOLDS WITH CRACKING = NON-PLASTIC CLAY
- IF IT CANNOT BE REMOLDED IT IS SILT, AND
- IF IT COULD NOT BE MOLDED AT ALL = NON-PLASTIC SILT.

ORGANIC, PEAT OR MUCK? IS IDENTIFIABLE BY ITS BLACK OR DARK BROWN COLOR, ITS VISIBLE PLANT REMAINS, ITS SPONGY FEEL AND ORGANIC ODOR.

Good load-bearing soils have a spectrum of sand and gravel sizes, and thus are well graded.

Pure silts have a very low dry strength which is a clear indication of their lack of foundation-bearing potential.

The plasticity of pure clay is a clue to possible land slippage under loads.

Organic soils, peat and muck are compressible and weak, and not load-bearing soils.

IT IS THE FINE RANGE OF SAND, CLAY, SILT COMBINATIONS THAT MUST BE RECOGNIZED IN PARTICULAR:

	DRY STRENGTH: THUMB TEST	TIME TO SETTLE IN WATER:	PLASTICITY: THREADING/ MOLDING POTENTIAL
SANDY SILT	NO STRENGTH	◦ 30 SEC - 60 MIN.	POOR
SILT	VERY LOW	15 MIN - SEV. HRS.	POOR
CLAYEY SILT	LOW	15 MIN. - SEV. HRS.	MEDIUM
ORGANIC SILT	LOW - MED.	15 MIN. - SEV. HRS.	POOR
SANDY CLAY	LOW - HIGH	◦ 30 SEC. - 2 HRS.	MEDIUM
CLAY	HIGH - VERY H.	◦ HRS. - DAYS	GOOD
SILTY CLAY	MED. - HIGH	15 MIN - SEV. HRS.	MEDIUM
ORGANIC CLAY	MED - VERY H.	◦ HRS. - DAYS	GOOD

TEST BORINGS ARE ALSO A NECESSITY ON ANY SITE, TO IDENTIFY THE SOIL LAYERS OR HORIZONS, AND BEDROCK LOCATION

ref: 4, 7, 5, 9, 17

Soil Identification

Soil Characteristics:

	STABILITY WHEN LOADED	AS BEARING FOR FOUNDATIONS	AS BASE FOR ROADS	DRAINAGE/PERCOLATION	ACIDITY	EROSION RESISTANCE	GENERAL DESIGN IMPLICATIONS
CLEAN GRAVELS (WELL GRADED)	EX.	EX.	GD.	EX.			WELL DRAINED, STABLE, BEARS LOADS
SILTY AND CLAYEY GRAVELS	GD.	GD.	PR.	NONE/FR.			HAS POTENTIAL
CLEAN SANDS (WELL GRADED)	EX.	GD.	PR.	EX.			WELL DRAINED, GOOD FOUNDATION IF GRADED IN SIZE
SILTY AND CLAYEY SANDS	PR/GD.	FR/GD.	PR.	NONE/FR.			HAS POTENTIAL
NON-PLASTIC SILTS (SANDY)	PR/GD.	PR/FR.	PR.	PR/FR.			STABLE; BUT WILL COMPRESS, OR HEAVES WHEN WET.
ORGANIC SILTS	PR/FR.	PR.	NOT	PR.	GD.		SERIOUS PROBLEMS
PLASTIC SILTS (LOESS)	PR.	PR.	NOT	PR/FR.			IF DRY, CAN BE GOOD BEARING SOIL; POSSIBLE SLIPPING
NON-PLASTIC CLAYS (SANDY)	FR.	PR/FR.	NOT	NONE/FR.			
ORGANIC CLAYS	PR.	NOT	NOT	PR/FR.	EX.		
PLASTIC CLAYS	PR.	NOT	NOT	NONE	EX.		
PEAT AND MUCK	NONE	NOT	NOT	PR/FR.			NOT AN ENGINEERING MATERIAL ELASTIC, WEAK, LITTLE COHESION.

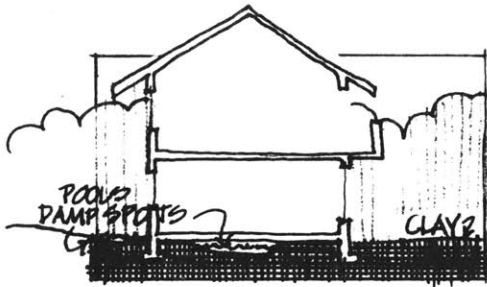
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THE SOILS WHICH PROPOSE SPECIFIC PROBLEMS FOR CONSTRUCTION INCLUDE:

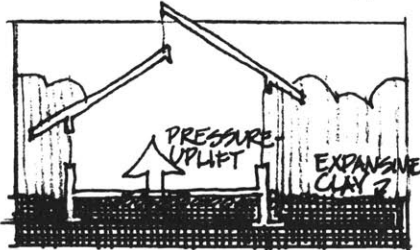
CLAY: CLAY IS COMPOSED OF CRYSTALLINE FLAKES OF ALUMINA, SILICA, OXYGEN, HYDROGEN, HYDROXYLS, AND IS THE SMALLEST OF GRAIN SIZES. IT IS OFTEN FOUND IN LOW AREAS, OR AREAS ADJACENT TO WATER. WITH COMPACTION, CLAY IS VIRTUALLY AN IMPERVIOUS MASS, AND POOLS DUE TO POOR DRAINAGE ARE FREQUENT. UNDER CONTINUOUS PRESSURE, CLAY WILL CREEP AND SLIP ON ITSELF, OR ANOTHER SOIL. PREVIOUSLY UNCOMPACTED CLAY IS FULL OF VOIDS AND HAS A TENDENCY TO CHANGE STRUCTURAL CHARACTER WITH THE ADDITION OF WATER - EXPANDING AND SHIFTING.

SILTS: SILT IS A LOOSE SEDIMENTATION, OF MINERAL CONTENT SIMILAR TO CLAYS, BUT LARGER IN PARTICLE SIZE, AND WITH WEAKER COHESIVE FORCES. SILTS ARE PREVALENT AT THE MOUTHS OF RIVERS, IN MARSHES, OR IN GENERAL TRANSPORTED OR COEXISTANT WITH WATER. DUE TO THEIR LOOSE PARTICLE BONDING, SILTS (ESPECIALLY ORGANIC SILTS) ABSORB AND RETAIN WATER, ARE SOFT AND UNSTABLE, WITH SERIOUS SHIFTING UNDER LOADING. LOESS IS A PLASTIC SILT THAT HAS BEEN WIND DEPOSITED, IS FILLED WITH VOIDS, AND IS CRUMBLY. DUE TO ITS POROUSNESS, LOESS IS RESPONSIVE TO THE DRIVING RAIN. RAIN EASILY CREATES VERTICAL CHANNELS IN THIS SILT, AND CAN INCREASE ITS NATURAL MOISTURE OF 10%, TO GREATER THAN 25%, AT WHICH TIME ITS SUPPORTING CAPACITY IS LOST, RESULTING IN EXCESSIVE SETTLING (8" - 2 FT.).

DESIGN IMPLICATIONS



Good surface drainage must be provided for clayey soils, to prevent foundation corrosion and damp basements.



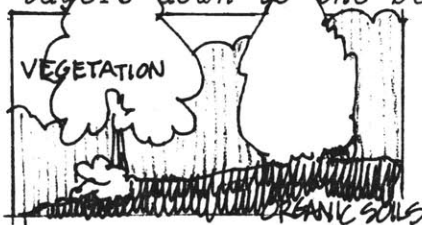
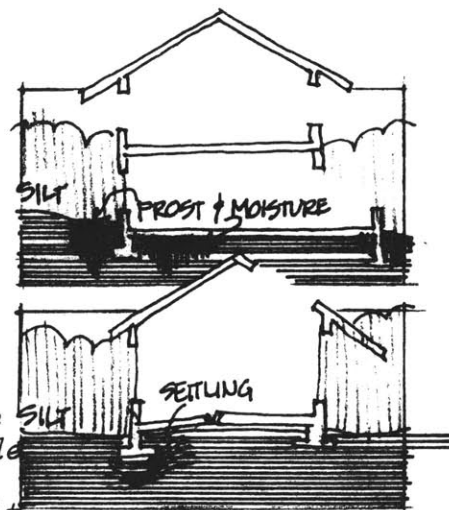
Design footings and foundation slabs to resist the uplift common in expansive clays. Volume change can be prevented by keeping the clay dry, although extremely difficult. For footing stability, the extension of piles and caissons to an inactive soil zone. Below the expansive clay zone may be the best solution.



Care must be taken to pin foundations over clay against slippage or creep under uneven pressures.

Whenever building foundations must be placed in organic silts, which absorb and retain water, design for the wet basements and serious frost conditions which will result. The addition of sand to either silts or clays may improve drainage, thereby reducing the damaging effect.

Silt is a poor soil choice under foundation footings due to its instability. Possible solutions to the problem of construction on silts include completely replacing silt with stabler soils, or driving piles through the silt layers down to the bearing soil.



Organic soils are highly compressive, retain water easily, and are generally unsuitable for building. However, organic soils are ideal for cultivating gardens and crops, and should be relocated on the site when there are no alternatives for building placement.

REFERENCES: 2, 4, 7, 9.
T. SCHNADELBACH

Soil Characteristics:

Soils & Air Temperatures:

CLUES

COLORS: THERE IS LESS REFLECTED HEAT AND COOLER AIR OVER DARK SURFACES, WHICH HAVE A LOWER ALBEDO OR REFLECTIVITY, THAN LIGHT SURFACES.

BLACK	10% REFLECTIVITY
DK. BROWN	10-15%
GREY, CEMENT, METAL	15-25%
LT. BROWN, BLUES	25-30%
PALE COLORS, STRAW	45-50%
WHITE	50-60%

HOWEVER, THE LOWER REFLECTIVITY IMPLIES HIGHER ABSORPTION, AND THE POSSIBILITY OF RETENTION FOR LATER RERADIATION.

TEXTURES:



- HIGHLY TEXTURED OR MATTE, SOIL SURFACES REFLECT LESS LIGHT AND HEAT DIRECTLY, AND THUS ABSORB MORE. SMOOTH SURFACES ON THE OTHER HAND REFLECT MORE HEAT INTO THE AIR.
- DENSE SOILS ARE HIGHLY CONDUCTIVE WITH LOWER HEAT CAPACITY, IN COMPARISON TO POROUS MATERIALS WHICH CONDUCT HEAT POORLY, BUT MAY RETAIN IT WELL.

WETNESS: WETTING SOILS REDUCES REFLECTION FROM 33-50%. IN GENERAL, MOIST SURFACES, ESPECIALLY BODIES OF WATER HAVE: LOW ALBEDOS (LITTLE REFLECTION EXCEPT FOR SPECULAR); HIGH CONDUCTIVITY; AND GOOD HEAT CAPACITY OR RETENTION.

HEAT: WHEN SURFACES ARE EXTREME HOT OR COOL TO THE TOUCH, IT IS A SIGN OF HIGH SURFACE CONDUCTIVITY AND A WIDE TEMPERATURE RANGE BETWEEN THE SURFACE AND THE BODIES WITHIN. ROOM TEMPERATURES, HIGHLY CONDUCTIVE SURFACES (METAL AND STONE) WILL DRAW HEAT FROM THE BODIES THAT TOUCH THEM, RESULTING IN COLD HANDS, SEATS OR FEET.

GENERAL INFORMATION

SOIL CLIMATES

IN DETERMINING THE SUN AND TEMPERATURE EFFECTS OF DIFFERENT SOILS, THERE ARE THREE BASIC ISSUES:

- SOIL REFLECTION, OR ALBEDOS, OF SOLAR RADIATION.
- SOIL ABSORPTION, OR CONDUCTIVITY, OF THE HEAT & RADIATION PRESENT.
- SOIL RETENTION, OR HEAT CAPACITY, OF ABSORBED HEAT FROM THE SITE.

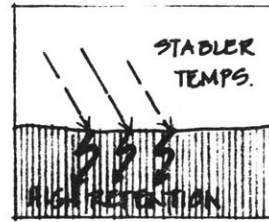
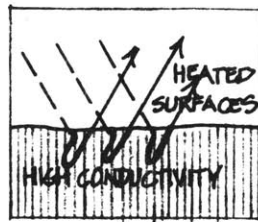
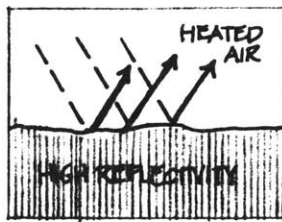
AIR TEMPERATURE RELIES ON ALL THREE OF THESE ISSUES: SOIL REFLECTIVITY, CONDUCTIVITY, AND RETENTION FOR LATER RERADIATION.

REFLECTIVITY: SURFACE MATERIAL SELECTION ALBEDO IS THE FRACTION OF RADIANT ENERGY, INCIDENT TO A SURFACE, WHICH IS REFLECTED BACK. THE HIGHEST ALBEDO, OF 100%, IS A PERFECT MIRROR. THE LOWEST A BLACK MATTE SURFACE. GENERALLY, ALBEDO IS THE PERMEABILITY OF A SURFACE TO THE FLOW OF RADIATION IN EITHER DIRECTION, SO LOW-ALBEDO SURFACES WHICH HAVE ABSORBED HEAT ARE OFTEN QUICK TO RERADIATE, WHILE HIGH-ALBEDO SURFACES ARE RESISTANT TO HEAT LOSS.

CONDUCTIVITY: SOILS AND TOPSOILS CONDUCTIVITY REFERS TO THE SPEED WITH WHICH HEAT PASSES THROUGH A MATERIAL, WITH HEAT FLOWING RAPIDLY THROUGH HIGHLY CONDUCTIVE SOILS. HIGHLY CONDUCTIVE MATERIALS CAN BE USEFUL IF THE GIVEN SOILS ALSO HAVE GOOD HEAT CAPACITY, BUT DETRIMENTAL WHEN THE HEAT RETENTION OF THE SOILS IS ONLY SHORT RANGE, IN WHICH CASE THE GROUND WILL REHEAT THE AIR IMMEDIATELY. THE CONDUCTIVITY OF NATURAL MATERIALS INCREASES WHENEVER THEY ARE WETTER, MORE DENSE, OR LESS POROUS.

HEAT RADIATION: SUBSOIL SELECTION. SOILS WITH GOOD HEAT RETENTION PROVIDE A SLOW RERADIATION TO THE SITE. THIS RESULTS IN A MILD AND STABLE MICROCLIMATE, WITH EXCESS HEAT STORED WHEN TEMPERATURES ARE HIGH, AND RELEASED WHEN TEMPERATURES DROP. IN PARTICULAR, MATERIALS WITH LOW ALBEDOS AND HIGH CONDUCTIVITY, SUCH AS WATER, SANDY SOILS, AND VEGETATION, WILL MODERATE EXTREME TEMPERATURE VARIATIONS BY RAISING MINIMUMS AND LOWERING PEAKS.

DESIGN IMPLICATIONS



CONSIDER THE RESULTING LOCAL TEMPERATURES IN DETERMINING SOILS AND SURFACE MATERIALS.

EXTREME DIVERSITIES IN MICROCLIMATES CAN BE ATTRIBUTED TO THE VARIOUS NATURES OF SURFACES UNDERLYING THE AIR LAYER...

ALBEDOS/REFLECTIVITY %

FRESH SNOW	75-95
COARSE GRAVEL	80-90
LT. GRAY LIMESTONE	80-90
OLD SNOW	40-70
LIGHT SAND	30-60
CLEAN ICE	30-50
SANDY SOIL	15-40
FIELDS, MEADOWS	15-30
WOODS	5-20
DK. CULTIVATED SOIL	7-10
WATER SURFACES	3-10%

Prevent the rapid heating of surface air, by minimizing the number of highly reflective surfaces in summer. In general, materials with high albedos (coupled with low conductivities) do not help balance the shifts in weather and cause extreme climates.

SURFACE TEMP./CONDUCTIVITY

AIR TEMP.	77°
RICH SOILS	79°
VEGET. CANOPIES	80°
GRASS	85°
BARE SOIL	93°
CONCRETE WALK	95°
SLATE ROOFS	110° F

The higher temperatures on roads, plazas or in the city are due to the fact that man made materials are in general highly conductive but can only retain their heat over a short period of time.

Use water and natural vegetation whenever possible to stabilize microclimate temperatures. In these materials excess heat is absorbed and stored to be released only when the temperature drops. Therefore, bodies of water might raise an average January temperature 5° F and decrease a July temperature 3-5° F. Temperature over planted grounds may be up to 10° cooler than exposed soil.

references: 2,4,5,14,7,0

: Soils & Air Temperatures :

Soils & Ground Temperatures

CLUES

VEGETATION:



THE FIRST SIGNS OF VEGETATION IN SPRING, AND THE FIRST GREEN PATCHES OF GRASS, OFTEN REVEAL THE WARMER AND WETTER SOILS, POINTING OUT SOILS WITH A HIGHER HEAT RETENTION.

WATERS:

THE PRESENCE OF WATER ON GROUND SURFACES INDICATES DENSER SOILS (WITH POOR PERCOLATION) AND HIGHER SURFACE CONDUCTIVITIES. THE HEAT RETAINING CAPACITY OF THIS SOIL PROFILE, IS THEN DETERMINED BY THE SUBSOILS PRESENT.

TOUCH:

SOILS WITH LONG-TERM HEAT RETENTION WILL MAINTAIN THEIR OWN HEAT, AND THUS DRAW LESS FROM THE BODIES THAT TOUCH THEM, GIVING SEMBLANCE OF A MODERATE SURFACE TEMPERATURE.

TOPSOIL & SUBSOIL TYPES DIRECTLY AFFECT THE SURFACE TEMPERATURE & AIR TEMPERATURE ABOVE GROUND, AS WELL AS THE POTENTIAL FOUNDATION TEMPERATURE BELOW GROUND.

GENERAL INFORMATION

GROUND TEMPERATURES

GROUND TEMPERATURE IS PRIMARILY DEPENDENT ON THE THIRD FACTOR OF SOIL CLIMATES: THE HEAT CAPACITY, OR HEAT RETENTION OF SOILS. SOILS MAINTAIN A STEADY TEMPERATURE OF $\sim 56^\circ$ WHICH IS USEFUL IN STABILIZING EXTREME TEMPERATURES THE YEAR ROUND. BASEMENTS ARE COOLER IN SUMMER, THROUGH HEAT LOSS TO THE SOIL, AND WARMER IN THE WINTER, WHEN THE TEMPERATURE DIFFERENCES (FROM INSIDE TO OUT) ARE LESS PRONOUNCED, (CONTRASTING SOIL AT 56° TO AIR AT $0-30^\circ$).

THE INFLUENCE OF SOIL TYPES:

CLAY SOIL HAS THE GREATEST SURFACE CONDUCTIVITY BECAUSE OF ITS DENSENESS, HOWEVER ITS WARMTH REMAINS AT THE SURFACE, AND IS RERADIATING QUICKLY.

SANDY SOIL (OR GRAVELS) HAS POOR HEAT CONDUCTIVITY ON THE SURFACE DUE TO ITS POROUSNESS AND HIGH QUANTITIES OF AIR, BUT HAS BETTER CONDUCTIVITY IN DEEPER AREAS (DUE TO A HIGHER DRY, PACKED DENSITY), ALONG WITH GOOD HEAT RETENTION FOR DELAYED RERADIATION.

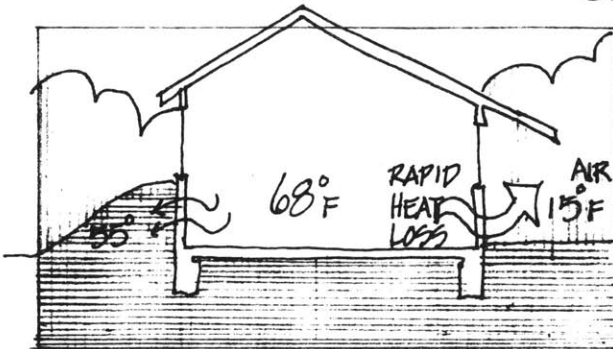
LOAM SOILS ARE MODERATE SOIL CLIMATES WITH BOTH MEDIUM VALUES OF HEAT CONDUCTIVITY AND HEAT RETENTION.

BEDROCK & DEEP CONCRETE ARE THE HIGHEST DENSITY MATERIALS AND HAVE HIGH SURFACE CONDUCTIVITY BUT POORER RETENTION; MAKING THEM LESS SUITABLE TO STABILIZE TEMPERATURE VARIATIONS THAN ANY OTHER SOIL MATERIAL.

THE ADDITION OF AIR: BOTH THE CONDUCTIVITY AND HEAT CAPACITY OF AIR ARE MUCH LESS THAN THOSE OF SOLID PARTICLES. AS A RESULT, GREAT TEMPERATURE SHIFTS OFTEN EXIST ABOVE SOILS CONTAINING LOTS OF AIR, WHICH HAVE MUCH LOWER VALUES OF CONDUCTIVITY AND HEAT CAPACITY. WHENEVER SOIL IS PLOWED THEN, MORE AIR IS INTRODUCED, WITH A LOSS OF HEAT BUDGETTING, AND A GREATER CHANCE OF FROST OCCURRING.

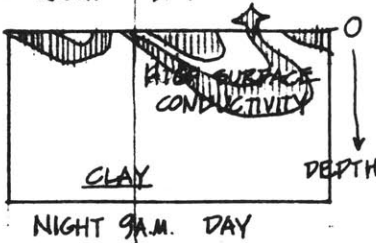
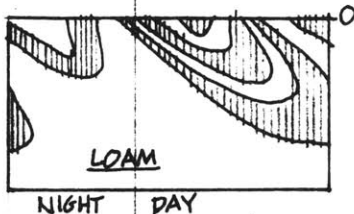
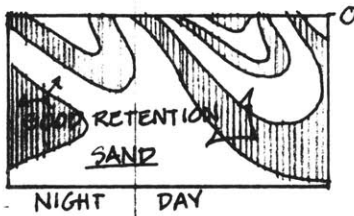
THE ADDITION OF WATER: WETTER SOILS HAVE BETTER HEAT CONDUCTIVITY AND HEAT CAPACITY THAN DRY MATERIALS. THIS KEEPS TEMPERATURES STABLE DURING EXTREME PERIODS. CAUTION MUST BE TAKEN IN WETTER SOILS HOWEVER, TO HANDLE FROST DEPTHS, THE EXTRA

DESIGN IMPLICATIONS

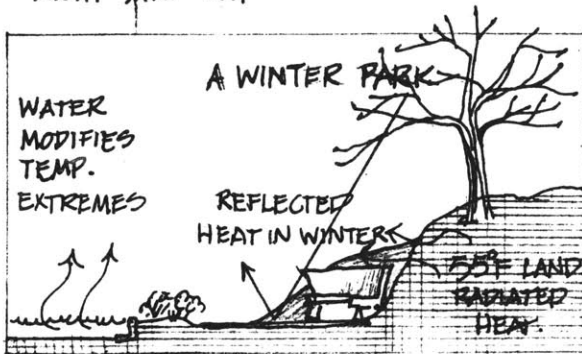


By using soil versus air to pack walls and foundations, a lesser temperature difference from inside to out is provided, which insulates the building against rapid heat loss. For the best insulation, build in sandy soil, which retains heat to greater depths during the day and releases heat in the evening, when needed most, in warm building walls and surface air.

TEMPERATURE IN RELATION TO DEPTH:



Clay soils, clayey loams, and bedrock will conduct heat rapidly and leave basement floor slabs cold. Therefore, for siting foundations, soils (such as sand, sandy loams, and gravels) should be chosen, with low conductivities to keep floors and walls warmer, but with good heat retention to reradiate during colder periods.



In addition, exposed reflective surfaces will quickly heat up the winter air in parks on sunny days, but are easily protected from the sun in summer. The inclusion of any body of water in a design solution helps stabilize the air temperature as reflecting little, absorbing heat over longer periods.

WEIGHT, AND THE CORROSION POSSIBILITY.

ref: 3, 5, 7, 8, 9, 4

Soils & Ground Temperatures

Soils & Erosion:

SOILS & WATER EROSION

THERE ARE TWO MAJOR ISSUES A DESIGNER MUST BE CONCERNED WITH TO PREVENT WATER EROSION:

① MAINTAINING TOPSOILS: IN GENERAL, TOPSOILS WITH A GREATER MINERAL CONTENT SUCH AS CLAYS AND SILTS, ARE LESS SUSCEPTIBLE TO WATER EROSION. SOILS WITH LESS MINERAL CONTENT (SANDS, LOAMS) ARE USUALLY MORE POROUS AND LOOSELY BOUND AND THUS EASILY CARRIED AWAY IN RAIN OR WATER RUNOFF.

② IN REDUCING MAJOR RUNOFF; HOWEVER, THESE DENSE AND MINERAL SOILS WHICH HOLD TOGETHER IN THE FACE OF WATER, OFTEN SPEED SURFACE RUNOFF BY BEING NONPOROUS AND SMOOTH. THIS CAUSES AN ACCUMULATED FORCE IN WATER RUNOFF WHICH MAY SERIOUSLY UNDERMINE BUILDING FOUNDATIONS, AND STRIP OFF TOPSOIL.

SO, TO PREVENT BOTH FORMS OF WATER EROSION, THE MOST EFFECTIVE SOIL HAS AN EQUAL AMOUNT OF ORGANIC MATERIAL TO MINERAL CONTENT. WHEN ORGANIC AND MINERAL MATERIALS ARE COMBINED, A SPONGELIKE SOIL IS PRODUCED, WHICH RESISTS TOPSOIL LOSS, AS WELL AS ABSORBS PRECIPITATION AND SURFACE WATER TO DIMINISH RUNOFF, AND POOLS OF STANDING WATER.

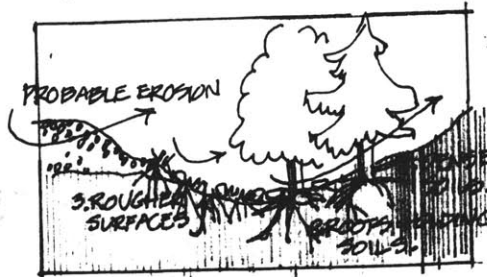


Prevent topsoil loss by using denser soils with greater mineral content. Then, prevent the fast surface runoff (which undermines building foundations) by introducing: 1) a large proportion of organic materials to increase absorption. 2) vegetation and rougher surfaces to slow the remaining runoff.

SOILS & WIND EROSION

WIND EROSION IS REDUCED BY ROUGHER SURFACES WHICH CAN MAINTAIN A PROTECTIVE AIR LAYER AT THE GROUND. FOR EXAMPLE, GRASS TRAPS A THICK AIR LAYER WHICH SERVES TO REDIRECT THE DAMAGING WINDS TO SLIGHTLY HIGHER CHANNELS. THIS AIR BLANKET ALSO SERVES AS INSULATION FOR PLAZA SURFACES AND UNDERGROUND STRUCTURES.

DENSER SOILS (SUCH AS CLAYS, ROCK, OR MINERAL SOILS) ALSO PREVENT WIND EROSION BY THEIR STRONG COHESIVE FORCES. ON THE OTHER HAND, LOOSELY BOUND SOILS (SUCH AS SANDS, SANDY SILTS, OR LOAMS) ARE OFTEN CARRIED AWAY BY EVEN SLIGHT WIND MOVEMENTS.



Prevent wind erosion by providing denser soils, rougher soil surfaces, and retaining vegetation. In windy slopes, give preference to clays, rocks and mineral soils which check wind erosion. Avoid loosely bound soils such as silts, sandy silts, or loams which are easily carried away.

Corrosion by Soils:

29



ABUNDANT EARTH-WORMS ARE A RELIABLE INDEX OF FERTILE SOIL, AND LOW ACIDITY.

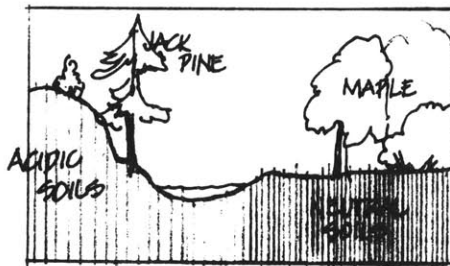
- THE BRIGHT FALL COLORS OF NEW ENGLAND INDICATE HIGH ACIDITY.

TREES INDICATE SOIL ACIDITIES:

MOSS	3.5-5	
JACK PINE	4.5-5	DOUGLAS FIR 6-7
EUR. BIRCH	4.5-6	COLORADO SPRUCE 6-7
WHITE PINE	4.5-6	BLACK OAK 6-7
HEMLOCK	5-6	
RED PINE	5-6	SUGAR MAPLE 6-7.5
BEECHS	5-6.7	SYCAMORE 6-7.5
PIN OAK	5-6.5	BLACK WALNUT 6-8
WHITE OAK	5-6.5	

SOIL ACIDITY:

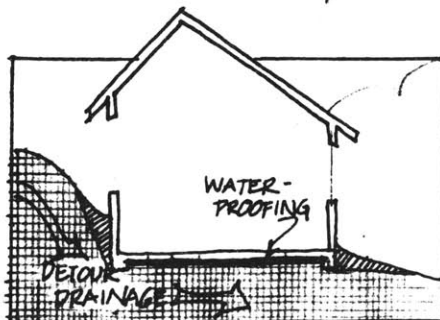
THE DIFFERENT ACIDITIES OF SOILS ARE VERY SIGNIFICANT IN THE CHOICE OF SURFACE FINISHES AND CONSTRUCTION MATERIALS, AS WELL AS IN THE CHOICES OF VEGETATION. ON A SCALE OF ACIDITIES, OR PH FACTORS, VALUES RUN FROM 0 TO 14, WITH 7 REPRESENTING NEUTRALITY, NUMBERS LESS THAN 7 FOR INCREASING ACIDITY, AND NUMBERS GREATER THAN 7 FOR INCREASING ALKALINITY. WHENEVER PH'S ARE LOWER THAN 4 OR GREATER THAN 8 OR 9, PIPES LAID IN THE GROUND WILL CORRODE, NOT TO MENTION LESS RESISTANT FOUNDATIONS. HUMID REGIONS OFTEN HAVE ACIDIC SOILS, WHILE DRIER AREAS MAINTAIN ALKALINE SOILS.



Determine the acidity of the soils on the site through observation and testing, then prevent corrosion by proper sealing materials and surface selection.

WATER SATURATION:

SOILS SATURATED WITH WATER ALSO HAVE A TENDENCY TO CORRODE BUILDINGS, BY THE CONTINUAL FREEZING AND THAWING OF FOUNDATIONS AND FLOOR SLABS, BY THE ACIDITY OF THE WATER, & BY THE DEEPER FROST POTENTIAL.



Provide adequate drainage around submerged foundations, as well as good waterproofing; to prevent corrosion by water.

references: 9, 17

Soils & Groundwater Drainage :

CLUES

SOIL APPEARANCE :

DARK COLORED SOILS, GENERALLY CONTAIN HIGH AMOUNTS OF DECAYED ORGANIC MATTER, AND THUS ARE USUALLY POORLY DRAINED WITH VERY POOR PERCOLATION.

SOILS WITH POOR PERCOLATION ARE OFTEN CHARACTERIZED BY MOTTLED TOPSOILS AND RED OR YELLOW (IRON) STAINS IN THE SUBSOIL.

GENERAL INFORMATION

THE DRAINAGE OF DIFFERENT SOILS, AND THE EFFECT THIS HAS ON BUILDING, INVOLVES THREE POINTS:

INFILTRATION & PERCOLATION: IS THE PROCESS BY WHICH WATER ENTERS, AND THEN MOVES THROUGH THE SOIL IN RESPONSE TO GRAVITY AND THE DOWNWARD PULL OF SOIL PORES. SOILS WITH HIGH PERCOLATION RATES, SUCH AS SANDS AND GRAVELS, ALLOW FOR THE RAPID DRAINAGE OF SURFACE WATERS. A LOW PERCOLATION RATE IS ATTRIBUTED TO WETLANDS, WHERE THE DENSITY OF SOIL STOPS WATER SEEPAGE, CAUSING STANDING WATER. IN GENERAL, THE FINER THE SOIL GRAINS - ALLOWING FOR EASY COMPACTION - THE LOWER THE RATE OF PERCOLATION. (THE ADDITION OF PLANT AND ANIMAL DECAY TO THESE FINE TEXTURED SOILS HAS AN EVEN MORE SEVERE CLOGGING EFFECT, CALLED HARDPAN, AND CAN STOP PERCOLATION ALTOGETHER.

POROSITY: IS THE DEGREE TO WHICH THE SOIL MASS IS PERMEATED WITH PORES OR CAVITIES. THUS, THE AMOUNT OF GROUND WATER CONTAINED IN A SOIL DEPENDS UPON ITS POROSITY. THE WATER IS EITHER RETAINED BY MOLECULAR ATTRACTION TO THE SOIL PARTICLES, OR CONTAINED IN INTERSTICES AND PORES. THE PROPORTION OF GROUNDWATER WHICH IS POTENTIALLY MOBILE, WILL DEPEND PARTLY ON HOW MANY OF THE INTERSTICES CONTRIBUTING TO THE OVERALL POROSITY ARE INTERCONNECTED. GOOD POROSITY, THEREFORE CAN EITHER IMPLY VERY MOIST SOILS WITH WATER CIRCULATING (OR MOBILE), OR SATURATED SOILS WHERE THE WATER IS STRAPPED.

	PERCOLATION	POROSITY (RETENTION)
LIMESTONE	GD	NONE
CLEAN GRAVELS	GD	LOW
SANDS & GRAVELS	GD	LOW
CLEAN SANDS	GD	LOW
FINE SANDS	PR	MED.
SILTY, CLAYEY SANDS	PR	HIGH
ORGANIC SILTS	PR	HIGH LITTLE MOBILITY
PLASTIC (CLAY) SILTS	PR	HIGH IMMOBILE
PLASTIC CLAYS (HOMO)	NONE	HIGH IMMOBILE
NON-PLASTIC CLAYS (SANDY)	PR	HIGH IMMOBILE
SANDY LOAMS	PR	HIGH LITTLE MOBILITY

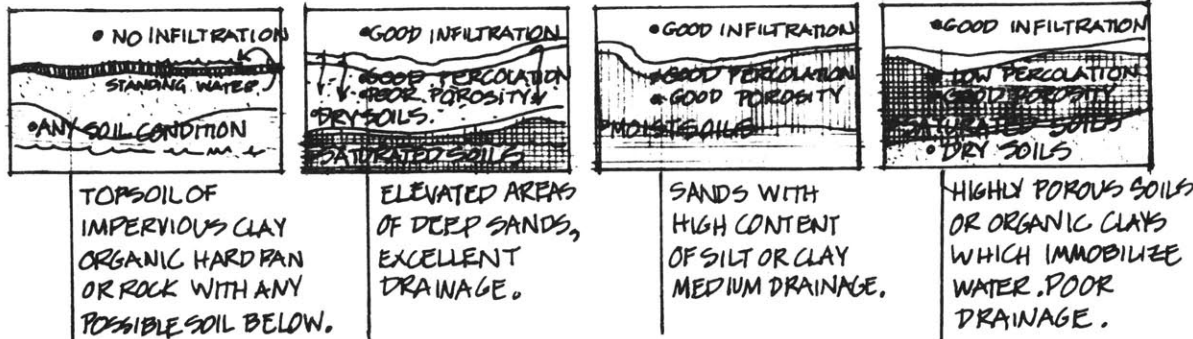
THE POROSITY OF SOIL IS PRIMARILY DEPENDENT ON:

- 1) THE NUMBER AND SIZE OF PORES, OR OPENINGS, IN THE SOIL, WHICH IN TURN IS LARGELY DEPENDENT ON THE SIZE OF THE PARTICLES AND THEIR PACKED ARRANGEMENT IN THE SOIL PROFILE.

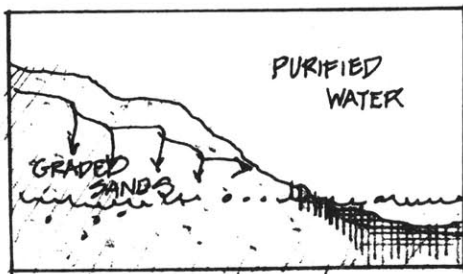
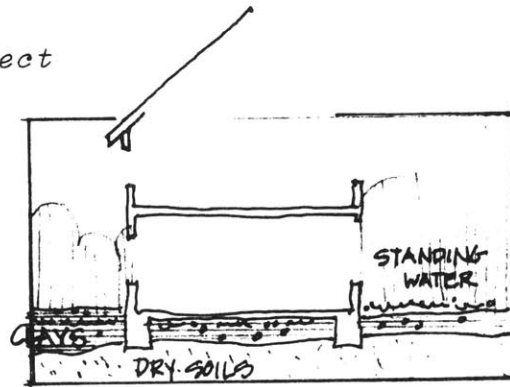
- 2) THE PERMANENCY OF THESE PORES. IN STORMS, SOILS OFTEN MELT OR BREAK DOWN AND FILL SOIL CAVITIES, ALLOWING FOR LESS PERCOLATION AND RETENTION.

- 3) THE TOTAL VOLUME OF PORES ALREADY OCCUPIED BY WATER. GENERALLY, WET SOILS ARE LESS POROUS THAN DRY ONES, SINCE MANY OF THEIR CAVITIES ARE ALREADY SATURATED.

DESIGN IMPLICATIONS

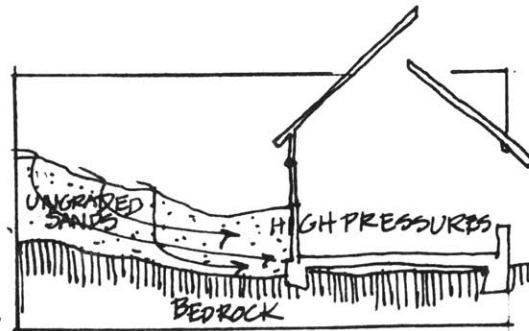


Impervious soils (with little or no infiltration) result in wet smelly ground surfaces which corrode foundations, cause extended frost pockets, and subject basement slabs to freeze-thaw action. Standing pools of water will exist on heavy soils, such as clay, and on soils whose openings have been clogged by fine particles. Over these nonpercolating soils, then, an intermediate soil, such as a bed of gravel, must be placed to provide adequate drainage for the building foundation



The good percolation of graded sands, some silts and certainly loams, will allow sewage to drain at a proper rate. By purification, soil chemicals and bacteria prevent sewage and drainage from polluting ground waters.

Well-graded soil mixtures with adequate drainage, will slow subsurface water runoff and thus prevent high pressures on foundations and potential water infiltration. If the soil is not well graded, or has poor drainage, the building should be relocated, or foundations reinforced. Watertight construction and waterproofing must also be provided.

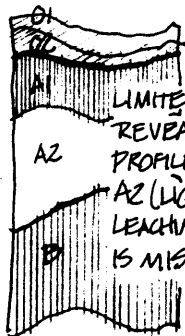


Soils & Groundwater Drainage:

ref: 9, 13, 21, 40

Soil & Moisture:

CLUES



LIMITED RAINFALL IS REVEALED IN SOIL PROFILES WHEN THE AZ (LIGHT COLORED LEACHING) HORIZON IS MISSING.

REDUCED SURFACE DRAINAGE

FROST DEPTH HAS MUCH TO DO WITH THE WINTER INFILTRATION CAPACITY OF SOILS. INCREASED SURFACE RUNOFF AND STANDING POOLS OF WATER WILL INDICATE RELATIVELY IMPERMEABLE FROZEN SOILS.

VEGETATION.



A COVER OF VEGETATION, SNOW OR EVEN PINE NEEDLES CAN KEEP THE SOIL FROM SEVERE FROST, AND 'CONCRETE' FREEZING WHICH UNDERMINES FOUNDATIONS.

GENERAL INFORMATION

SOIL & PRECIPITATION

ALTHOUGH SOIL TYPE HAS LITTLE EFFECT ON PRECIPITATION, THE AMOUNT AND CONSTANCY OF PRECIPITATION HAS A SIGNIFICANT EFFECT ON SOIL CHARACTERISTICS. RAINFALL: IRREGULAR RAINFALL WILL RESULT IN GRAYISH SOILS WITH MINERAL DEPOSITS WHERE DRY HEAT HAS CAUSED A HIGH RATE OF EVAPORATION. IN REGULAR RAINFALL, SOIL REMAINS DAMP FOR A LONG TIME, WITH LESS EVAPORATION, WHICH ALLOWS PLANTS TO DECAY AND PRODUCE ACID SOILS.

SNOWFALL: THE ADDITION OF A LAYER OF SNOW ON ANY SOIL SURFACE, PROVIDES AN EXCELLENT INSULATION BLANKET. IN FACT, ONE FOOT OF SNOW IS BETTER THAN 2 FEET OF DRY SUBSOIL (AND A MUCH GREATER THICKNESS OF ROCK), FOR THE PURPOSE OF KEEPING GROUNDS FROM BEING FROZEN TO GREAT DEPTHS, AND FOR INSULATING NEAR BUILDING FOUNDATIONS.

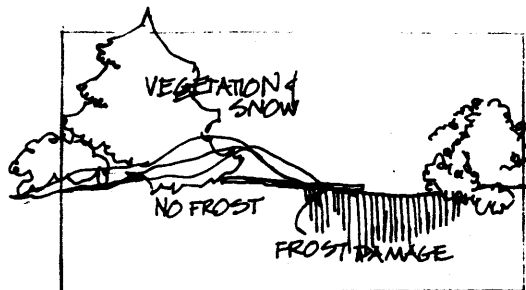
FROST DEPTH & DURATION

WHEN THE TEMPERATURE OF THE SURFACE OF THE SOIL IS BELOW FREEZING, AND THE WATER TABLE IS NOT TOO DEEP TO PREVENT CAPILLARY WATER RISE, THE MOISTURE MOVING UP SOILS BY CAPILLARY ACTION AND BY EVAPORATION-CONDENSATION ACTION, WILL FREEZE TO THE SURFACE OF SOIL PARTICLES. THIS IS KNOWN AS FROST ACTION, AND IS MOST PREVALENT IN FINE SANDS AND SILTS WHICH ARE CAPABLE OF LIFTING THE GREATEST AMOUNT OF WATER IN THE SHORTEST TIME BY CAPILLARY ACTION. TO A LESSER EXTENT, CLAYEY SOILS ARE ALSO SUBJECT TO THIS FREEZING. ON THE OTHER HAND, CLEAN SANDS OR GRAVELS (OR MIXED GRAIN SOILS) ARE DESIGNATED AS FROST FREE. THE FROST LINE IS THE DEPTH TO WHICH FROST USUALLY REACHES, BELOW WHICH THE GROUND RARELY FREEZES AND FOUNDATIONS REST SECURELY. WHEN BUILDING FOUNDATIONS ARE BUILT ABOVE THIS LINE, ONE RISKS THE POSSIBILITY THAT THE GROUND BELOW WILL FREEZE AND HEAVE CRACKING THE FOUNDATIONS AND MAKING THE BUILDING UNSAFE.

GROUND MOISTURE & HUMIDITY

SOILS WITH GOOD MOISTURE RETENTION, ARE MORE EFFECTIVE THAN DRY SOILS IN WARMING THE AIR DURING COLD PERIODS AND COOLING THE AIR WHEN HOT. THE ADDED MOISTURE STABILIZES TEMPERATURES BY ABSORBING AND HOLDING HEAT UNTIL THE TEMPERATURE DROPS, BUT ALSO INCREASES EFFECTIVE WINTER TEMPERATURE BY ADDING HUMIDITY TO THE AIR.

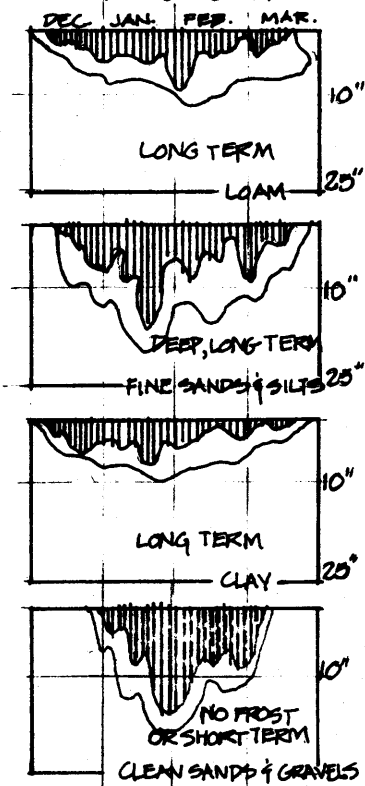
DESIGN IMPLICATIONS



1) Whenever possible, leave snow accumulation (and add vegetation) to act as an insulator for the soil, serving to stabilize ground temperature and prevent freeze-thaw damage.

2) Wetting soils in no-frost months will help stabilize air temperatures by retaining heat for cooler hours.

FROST DEPTH AND DURATION UNDER SNOW COVER.



For building stability, foundation footings must be placed below the frost line, a line which varies regionally as well as locally - depending on the type of soil. The national building code requires that buildings be placed one foot below this frost level.

To prevent corrosion and cracking, foundations must also be protected from the freeze-thaw action of frost. Frost damage can be prevented by removing all highly frost-susceptible materials within the depth of frost penetration, and replacing them with frost-free material. Often the expense of this is prohibitive, and frost-free materials can only be placed at the base of the foundation, or directly under pavements. Therefore, foundation materials must be chosen to withstand the corrosion and cracking effects of the frost.

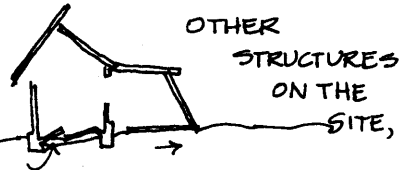
IN OTHER TERMS, SOILS WITH BOTH GOOD PERCOLATION AND GOOD POROSITY ARE SUBJECT TO THE SEVEREST FROSTS; WHILE SOILS WITH POOR PERCOLATION BUT GOOD POROSITY ARE SUBJECT TO MILDER FROSTS, AND SOILS WITH HIGH PERCOLATION BUT NO POROSITY ARE FROST FREE.

references: 5, 9, 13, 17 OTHERS. 4.

: Soil & Moisture:

Soils & Stability

CLUES

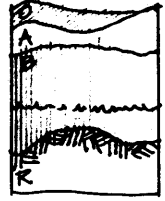


OR NEARBY SITES, ARE THE BEST INDICATION OF SOIL STABILITY. LOOK FOR UNEVEN BUILDING SETTLEMENT, BASEMENT CRACKS FROM GROUND SWELLINGS, OR LIGHT CONSTRUCTION (DECKS...) THAT MAY HAVE SLIPPED AWAY FROM THE MAIN STRUCTURES.

★ REMEMBER THAT DIGGING TO LAY FOUNDATIONS EXPOSES THE SUBSOILS TO ATYPICAL RAINFALL AND HOT SUNS, POSSIBLY CHANGING THE DISPOSITION OF THE SOILS SIGNIFICANTLY....

GENERAL INFORMATION

THE STABILITY OF DIFFERENT SOILS IS DEPENDENT ON THE SOIL PROFILE, AND SOIL CHARACTERISTICS:



THE BEARING ABILITY OF THE DIFFERENT SOILS
 WATER TABLE POSITION
 BEDROCK LOCATION

- 1. THE BEARING QUALITY OF SOILS**
 WHENEVER SOILS ARE SUBJECT TO SLIPPING, SHIFTING, SWELLING OR COMPACTION - THEIR BEARING STABILITY IS UNRELIABLE. SOILS THAT PROPOSE SPECIFIC PROBLEMS FOR CONSTRUCTION INCLUDE:
- 2. WATER TABLE POSITION**
 THE SPECIFIC PROBLEMS GENERATED BY THE WATER TABLE ITSELF WILL BE ADDRESSED IN THE NEXT CHAPTER. HOWEVER, THE POSITION OF THE WATER TABLE IN RELATION TO SOIL TYPES PROPOSES OTHER PROBLEMS:
 a) A FLUCTUATING TABLE CAUSES SWELLING AND CONTRACTING IN SILTS AND CLAYS, b) A HIGH TABLE INDUCES SHIFTING OF SANDS AND SLIPPING BETWEEN CLAY LAYERS, AND c) A PERCHED TABLE OVER ORGANIC HARD PAN LAYERS, IMPERMEABLE SOILS, OR ISOLATED PIECES OF BEDROCK, COULD CHANGE OR BE LOST COMPLETELY WHEN THESE SUPPORTING LAYERS ARE PUNCTURED.
- 3. BEDROCK LOCATION**
 USUALLY, BEDROCK HAS EXCELLENT STABILITY. FOUNDATIONS WHICH CAN BE BROUGHT TO BEAR ON BEDROCK ARE THE BEST. HOWEVER, WHEN BEDROCK IS TOO DEEP TO BE USEFUL, THE INTERMEDIATE LAYERS OF SOIL OFTEN HAVE TO SERVE AS THE FOUNDATION SUPPORT. IN THIS CASE, THE DEPTH AND TYPE OF EACH SOIL HORIZON MUST BE EVALUATED FOR STRUCTURAL STABILITY, AS WELL AS THE INTERFACE BETWEEN HORIZONS. LASTLY, SHALLOW BEDROCK DICTATES A DESIGN DEPTH (OR SITE RELOCATION), OR COSTLY BLASTING.

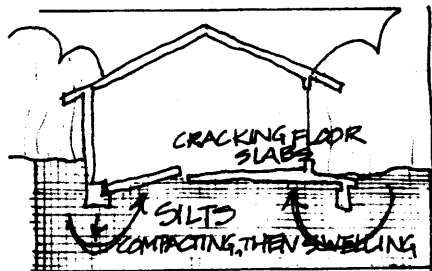
SOIL TYPES & FOUNDATIONS

CLEAN GRAVELS	UNNECESSARY	↑↑	FOOTINGS
CLEAN SANDS SILTY & CLAY SANDS			
SANDY SILTS LANDFILL SANDY CLAYS	↑↑	↑↑	FLOATING FOUNDATIONS
PLASTIC SILTS PLASTIC CLAYS			
ORGANIC SILTY CLAYS PEAT & MUCK WATER	↑	↑	END BEARING PILES NECESSARY

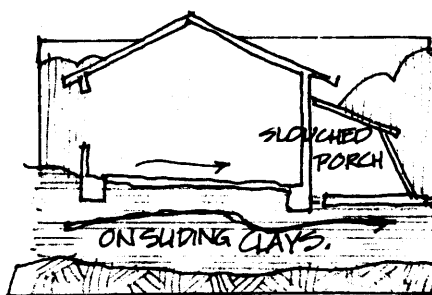
see implications

- FOUNDATION POSSIBILITIES:** THERE ARE THREE MAJOR METHODS OF CONSTRUCTING STABLE FOUNDATIONS, USING:
- ① PILES EITHER END-BEARING PILES (THROUGH ANY SOIL WITH LATERAL SUPPORT) OR FRICTIONAL PILES (WITH PLASTIC CLAYS OR MOIST SILTS, NOT IN WATER, LIQUID SOILS OR SHIFTY SANDS);
 - ② FLOATING FOUNDATIONS FOR LIGHT CONSTRUCTION OVER FILL, STIFF CLAYS, AND SILTY OR CLAYEY SANDS; AND
 - ③ SIMPLE FOOTINGS ON ANY STABLE, LOAD BEARING SOIL.

DESIGN IMPLICATIONS



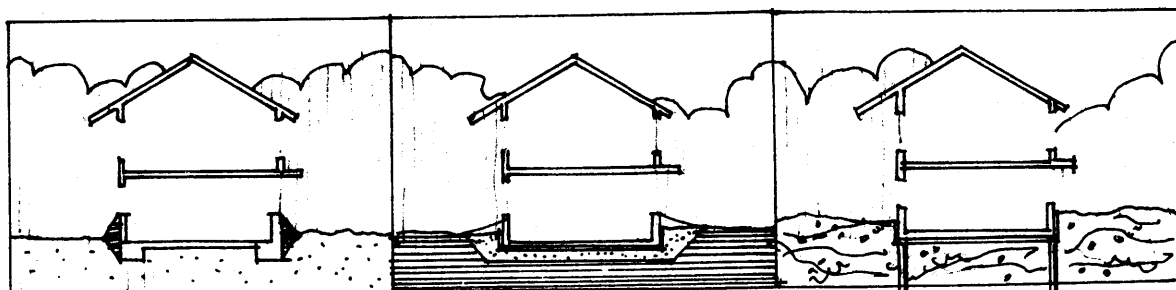
silty soils will compress under loads when dry, which often causes a lopsided settling in building foundations. When wet or frozen, silt is even more unstable. It swells and heaves badly, so foundations must either be carried to deep, stabler soils, or be elastic enough to cope with the heaving pressures and height variations.



Clays also swell when wet, heaving under foundation slabs. In addition, the crystalline flakes that compose clay allow one clay layer to slide on another, requiring the use of floating foundations, or piles which can reach the deeper soils with better bearing quality. Topsoil layers also slip on clay soils, implying that decks or light construction be carefully tied to the foundation structure or be anchored to stabler soil.

Uncontained sands, found particularly near bodies of water, are subject to continual shifting, with no point loading possible. Therefore, sands are unsuitable for stable foundations unless braced or contained.

In general, soils with higher mineral content - ranging from non-plastic clays and silts to bedrock - have good stability for building purposes. Organic soils on the other hand, are unfit for construction, being subject to both form and volume alterations under loads.



SIMPLE FOOTINGS ON CLEAN SANDS & GRAVELS, WHICH ALLOWS POINT LOADING; OR ON SILTY/CLAY SANDS WITH BIGGER FOOTINGS TO DISTRIBUTE THE LOAD OVER LESS STABLE SOIL.

FLOATING FOUNDATIONS ON FILL, STIFF CLAYS, SANDY SILTS WITH A LAYER OF CLEAN SANDS OR GRAVELS FOR DRAINAGE & A VAPOR BARRIER.

FRICTIONAL PILES IN SLIGHTLY STRUCTURAL SOILS SUCH AS PLASTIC SILTS/CLAYS. ENDBEARING PILES IN NON-BEARING PEAT, ORGANIC SOILS, WATER, LIQUID SOILS.

REFERENCES: 9, 19, 17, 21 OTHERS, 4.

Soils & Stability

33

Microclimate

Regional Climate Conditions

THE FIRST STEP IN SITE RECONNAISSANCE IS TO ESTABLISH THE OUTSIDE CONSTRAINTS ON THE SITE. THESE REGIONAL CLIMATIC CONDITIONS CAN BE EXPRESSED BY DATA ON: INSOLATION, TEMPERATURE, WIND SPEED AND DIRECTION, HUMIDITY AND PRECIPITATION. IN FACT, A SITE PLANNER MUST ESTABLISH THE REGIONAL CLIMATE AS PRIMARY DESIGN DATA, BEFORE LOCAL VARIATIONS CAN BE RECOGNIZED, BEFORE SITE SELECTION AND DESIGN MODIFICATIONS CAN BE SUGGESTED.

♦ GATHER REGIONAL CLIMATOLOGICAL DATA FROM NEARBY STATIONS OF THE U.S. NATIONAL WEATHER SERVICE. DO A RATHER THOROUGH JOB OF COLLECTING DATA ON:

REGIONAL THERMAL CONDITIONS: IN DEGREE DAYS, AND WET VS. DRYEULB TEMPERATURES.

✱ WHEN DOES THE EFFECTIVE TEMPERATURE MOVE OUTSIDE THE COMFORT ZONE?

REGIONAL SOLAR CONDITIONS: IN HRS. OF SUNSHINE VS. CLOUDY DAYS, SOLAR HEAT GAIN POSSIBLE, AND THE ANGLE AND DIRECTION OF THE SUN.

✱ AT WHAT TIME OF DAY OR DURING WHAT SEASON SHOULD SUN RADIATION BE AVOIDED OR INVITED, AND FROM WHAT DIRECTION?

REGIONAL WIND CONDITIONS: IN WIND DIRECTIONS & VELOCITIES.

✱ WHAT ARE THE FAVORABLE AND UNFAVORABLE WINDS?

REGIONAL PRECIPITATION CONDITIONS: AMOUNT AND FREQUENCY OF RAIN AND SNOW.

✱ WHAT IS THE DURATION AND INTENSITY OF PRECIPITATION THAT MUST BE Warded OFF & DRAINED AWAY?

AND FINALLY REGIONAL HUMIDITY DATA, FOR DIFFERENT MONTHS AND DIFFERENT TIMES OF THE DAY.

ONCE DONE, A REGIONAL ANALYSIS IS USEFUL AS PRIMARY DATA FOR ALL THE DESIGNING TO BE DONE IN THAT REGION.

" A SKETCHY EXAMPLE OF A REGIONAL CLIMATE ANALYSIS FOR BOSTON MIGHT INCLUDE THE CHART ON THE NEXT PAGE, AND A WRITTEN STATEMENT INCLUDING SUCH INFORMATION AS: IN BOSTON, OUTDOOR TEMPERATURES ARE FREQUENTLY ABOVE THE COMFORT ZONE IN JULY AND AUGUST, WHEN THE MOST USEFUL COOLING WINDS ARE FROM THE SOUTHWEST. IN THE EIGHT COLD MONTHS, THE PREVAILING WINDS ARE MUCH STRONGER AND COME FROM THE WEST AND NORTHWEST (WHERE SUNLESS SLOPES, COLD AIR FLOODS, AND EXPOSURE TO WINTER WINDS MUST ALL BE AVOIDED). PRECIPITATION IS HEAVIEST IN BOSTON FROM DECEMBER TO MARCH. SUNNY DAYS ARE MORE FREQUENT FROM AUGUST TO OCTOBER, WHICH UNFORTUNATELY IS ALSO THE PERIOD OF HIGHEST HUMIDITY.²⁰

THE FIRST STEP, THEN, IS TO ESTABLISH A SET OF REGIONAL CLIMATE DATA AND A RANGE OF IMPLICATIONS THIS MIGHT HAVE FOR DESIGN.

✱ SAMPLE QUESTIONS.

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MO. OF YEAR	INSOLATION		TEMPERATURE			WIND		MOISTURE	
	SUNSHINE HRS/MO.	% POSS. SUNSHINE	HEATING DEGREE DAYS/MO.	TEMPERATURE MO. OF DAY	TEMPERATURE MO. OF NIGHT	WIND SPEED MPH	PREVAIL. DIREC.	RELATIVE HUMIDITY %	
JAN.	148	50	1088	30°	33	26°	16	NW	68
FEB.	168	57	972	30°	38	27°	15	WNW	69
MAR.	212	57	846	38	41	34	14	NW	65
APRIL	222	56	513	48	52	44	14	WSW	67
MAY	263	59	208	59	63	54	12	SW	70
JUNE	283	62	66	68	72	63	12	SW	70
JULY	300	64	7	74	78	69	10	WSW	70
AUG.	280	64	15	72	76	67	11	WSW	70
SEPT.	232	63	98	65	69	61	11	WSW	78
OCT.	207	59	316	55	59	51	12	WSW	70
NOV.	152	50	603	45	48	41	13	WSW	70
DEC.	148	49	983	33	36	30	17	N.	70
TOTALS	2615	58%	5715	50	55	48	15	SW	69

references: 1, 15

CLIMATIC DATA: BOSTON 42°22'N

THE SECOND STEP IN SITE RECONNAISSANCE IS TO IDENTIFY LOCAL VARIATIONS IN THIS REGIONAL (MACRO) CLIMATE FOR THE SITE IN QUESTION. EACH SITE MUST BE LOOKED AT AS A SPECIAL CASE, FALLING WITHIN THE REGIONAL CLIMATIC RANGE, BUT WITH A VERY UNIQUE MICROCLIMATE WHICH OFTEN CHANGES WITHIN A DISTANCE OF A FEW FEET. DELICATE CHANGES IN TOPOGRAPHY, VEGETATION, OR GROUND THERMAL CAPACITY CAN STRONGLY INFLUENCE REGIONAL CLIMATES TO CREATE LOCAL VARIATIONS - WHICH HAVE IMPORTANT IMPLICATIONS FOR SITE AND BUILDING DESIGN.

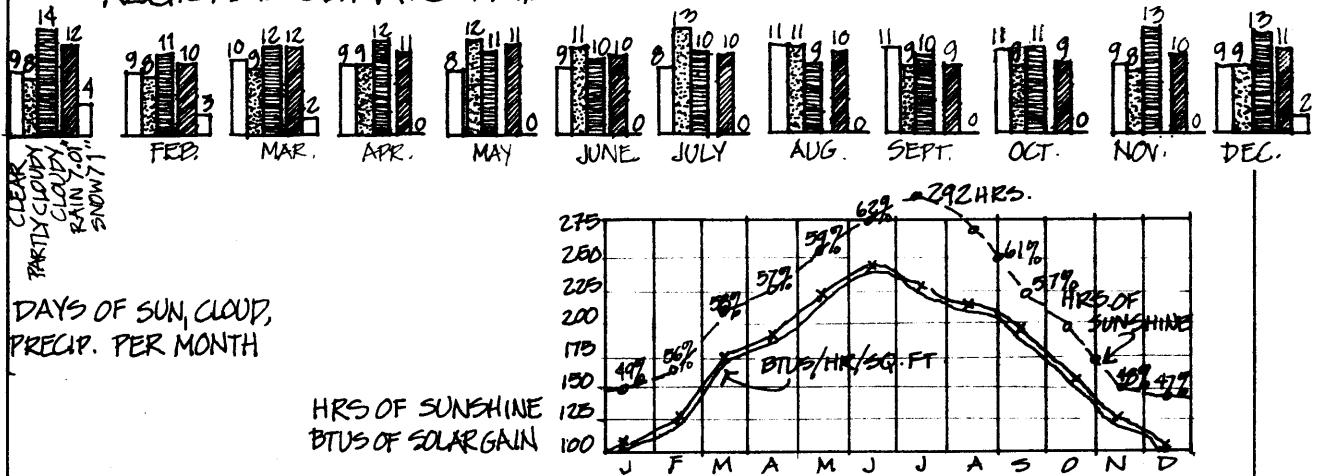
- ◆ GATHER TOGETHER INFORMATION ON THE PARTICULAR SITE:
CONTOUR MAPS, SITE CLIMATE RECORDS, SOIL AND WATER SURVEYS, BORINGS, SITE MAPS...
- ◆ ADD THE LOCAL PREDICTIONS MADE IN PREVIOUS CHAPTERS FROM EXISTING CONDITIONS AND OBVIOUS DANGER SIGNALS.
- ◆ AND FINALLY, MEASURE AND CALCULATE LOCAL SUN, TEMPERATURE, WIND, HUMIDITY AND PRECIPITATION CONDITIONS, BY METHODS OBTAINED IN THE FOLLOWING PAGES.

ONLY THEN CAN PHYSICAL MODIFICATIONS AND DESIGN SOLUTIONS BE DEVELOPED. IT IS IMPORTANT TO UNDERSTAND THE PHYSICAL IMPLICATIONS OF RECURRING WEATHER CONDITIONS TO BE ABLE TO DESIGN WITH THE NATURAL FORCES TO MAINTAIN HUMAN COMFORT.

:Regional Climate Conditions:

Measuring the Solar Microclimate:

REGIONAL CLIMATE DATA



BOSTONS SOLAR CONDITIONS:

- IN GENERAL, BOSTON ENTERTAINS YEARLY ABOUT 57% SUNSHINE HOURS OF THE TOTAL POSSIBLE SUN EXPOSURE. ALTHOUGH THE LEAST AMOUNT OF SUNSHINE IS IN WINTER, AND THE MOST IN SUMMER, SHADING IS STILL DESIRABLE FOR AT LEAST 60% OF THESE SUNSHINE HOURS.
- THE NUMBER OF CLEAR VERSUS CLOUDY DAYS ARE TYPICALLY HALF AND HALF IN BOSTON NUMBERING ABOUT 9 DAYS OF EACH PER MONTH IN WINTER, 11 OR 12 DAYS EACH IN FALL MONTHS, AND 12 TO 13 DAYS EACH IN SUMMER MONTHS.
- POSSIBLE SOLAR HEAT GAIN IN THE CITY AREA AMOUNTS TO 235 BTU'S/SQ.FOOT/HR ON A CLOUDY DAY IN JUNE OR JULY, AND 333 BTU'S.F./HR ON A CLEAR DAY, BUT ONLY 165 BTUS ON A CLEAR DAY IN JANUARY.
- HOWEVER, THE DIRECTION AND ANGLE OF THE SUN IN WINTER IS SO SIGNIFICANTLY DIFFERENT IN SUMMER, THAT ONE CAN MAXIMIZE THE 165 BTU'S OF WINTER HEAT GAIN, AND STILL AVOID THE HIGH BTU EXPOSURE IN SUMMER. FOR EXAMPLE, VERY STEEP/VERTICAL SURFACES WILL RECEIVE MUCH MORE HEAT IN WINTER THAN LEVEL GROUND, AND MUCH LESS HEAT IN SUMMER.

THE DESIGN CRITERIA

- KNOWLEDGE OF THE SUNS APPARENT MOTION IN THE SKY, AS WELL AS THE SEASONAL TEMPERATURE IT PRODUCES, CAN SERVE AS A BASIS FOR DESIGN, IN RESPONSE TO SEASONAL NEEDS FOR THE SUNS' HEAT.
- RADIATION IS GENERALLY ONLY UNDESIRABLE IN BOSTON'S THREE HOT MONTHS, AND VARIOUS DEVICES CAN BE USED TO AVOID IT (SHADOWING, VEGETATION, HEAT RETAINING MATERIALS). IN THE COLD MONTHS HOWEVER, RADIATION IS DESIRABLE - SO ALTHOUGH BIG EXPOSURES CREATE PROBLEMS OF SURFACE HEAT LOSS, THEY ARE OFTEN PREFERRED FOR THE GAINED INSOLATION.
- AS A MEANS OF DESIGNING FOR BOTH WINTER AND SUMMER NEEDS THEN, USE THE ANGLES OF THE SUN AS A DESIGN STANDARD - ADMITTING LOW RADIATION INTO THE SITE IN WINTER, BUT SHIELDING FROM THE HIGH RADIATION IN SUMMER.

THE AMOUNT OF RADIATION RECEIVED BY A SITE DEPENDS ON SEVEN FACTORS:

- | | |
|---|---|
| A | 1. THE NUMBER OF CLEAR VERSUS CLOUDY DAYS - GIVEN.
2. THE POSITION OF THE SUN ACCORDING TO THE TIME OF DAY, (SUN INCLINATION).
3. THE POSITION OF THE SUN ACCORDING TO THE SEASON, (SUN ORIENTATION). |
| B | 4. THE DIRECTION OF THE SLOPE OF THE STATION POINT.
5. THE ANGLE OF THE SLOPE OF THE STATION POINT.
6. THE HEIGHT OF THE STATION
7. THE SURROUNDINGS, SETTING. |

ALL DEPEND ON SITE

A. DETERMINING THE INCLINATION AND ORIENTATION OF THE SUN AT ANY TIME OF DAY, FOR ANY SEASON, FOR A SITE 42° N LATITUDE.

IN GENERAL, IT IS ONLY NECESSARY TO CALCULATE SUN ANGLES FOR MIDWINTER, MIDSUMMER, AND THE TWO EQUINOXES, SPRING AND FALL. THESE IDENTIFY THE RANGE AND MIDPOINT OF THE SUN POSITIONS, ALLOWING OTHER TIMES TO BE ESTIMATED BETWEEN THEM. AT THE SPRING AND FALL EQUINOX, THE SUN APPEARS TO RISE DUE EAST AT 6 A.M., CLIMBING THEN FOLLOWING IN AN ARC THAT PEAKS AT HIGH NOON - AT AN ANGLE $90^{\circ} - \text{LATITUDE OF THE SITE}$. IN MIDWINTER, WHEN THE DAY IS SHORTER, THE SUN RISES AND SETS WELL TO THE SOUTH OF EAST AND WEST, WITH THE MAXIMUM ANGULAR HEIGHT (AT NOON) = $(90^{\circ} - \text{LATITUDE OF THE SITE}) - 23.5^{\circ}$. IN MIDSUMMER, THE DAY IS LONGER, RISING AND SETTING WELL TO THE NORTH OF E + W, AND THE SUN ANGLE REACHES A HEIGHT OF $(90^{\circ} - \text{LATITUDE OF THE SITE}) + 23.5^{\circ}$.

FOR BOSTON, WITH A LATITUDE OF $42^{\circ} 21'$, THIS IMPLIES SUN ANGLES FROM THE HORIZONTAL OF:

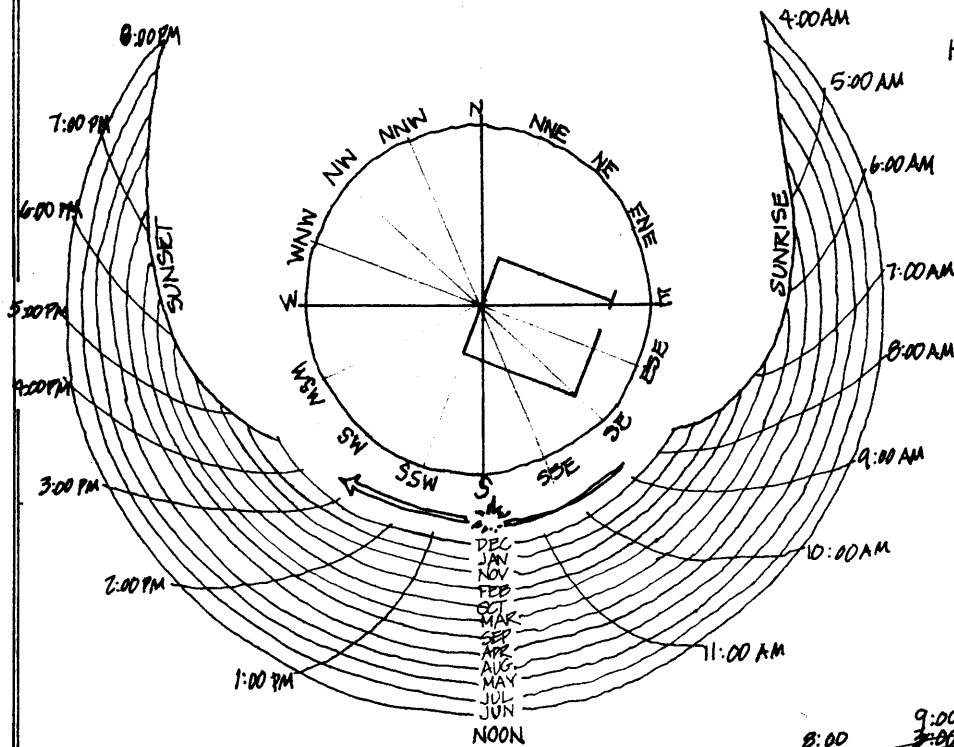
$$\begin{aligned} \text{EQUINOCTAL NOON} &= 90 - 42^{\circ} = 48^{\circ} \\ \text{MIDWINTER NOON} &= 24.5^{\circ} \\ \text{MIDSUMMER NOON} &= 71.5^{\circ} \end{aligned}$$

(continued)

references: 1, 15, 2, 11

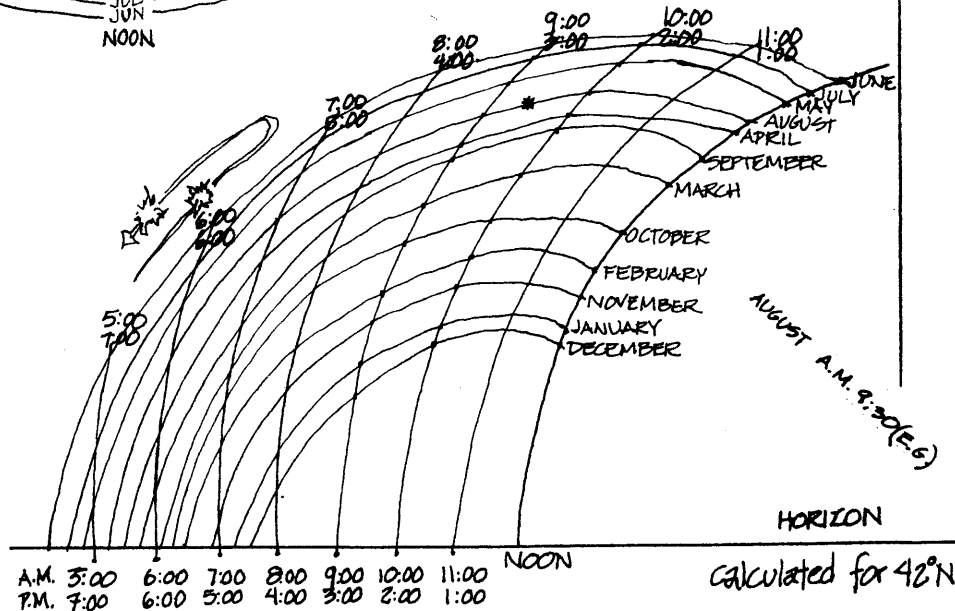
Measuring the Solar Microclimate.

Measuring the Solar Microclimate:



HOWEVER, KNOWING MORE PRECISELY WHERE THE SUN LIES, ITS DIRECTION AND ALTITUDE WITH EACH HOUR AND SEASON, GIVES A BETTER SENSE OF THE SHADOW AND EXPOSURE PATTERN ARISING FROM A GIVEN PLAN. THIS HELPS ANALYZE THE SIGNIFICANCE THAT A BUILDING OR SITE DESIGN MIGHT HAVE ON OVERALL INSOLATION.

FOR THIS PURPOSE, THESE TWO CHARTS - SHOWING THE AZIMUTH OR ALTITUDE OF THE SUN FOR EACH HOUR OF THE DAY AND MONTH OF THE YEAR - CAN HELP TO PLOT SHADOWS CAST BY VERTICAL FORMS, AND TO PREDICT THE MAXIMUM INSOLATION RECEIVED BY A GIVEN SURFACE.

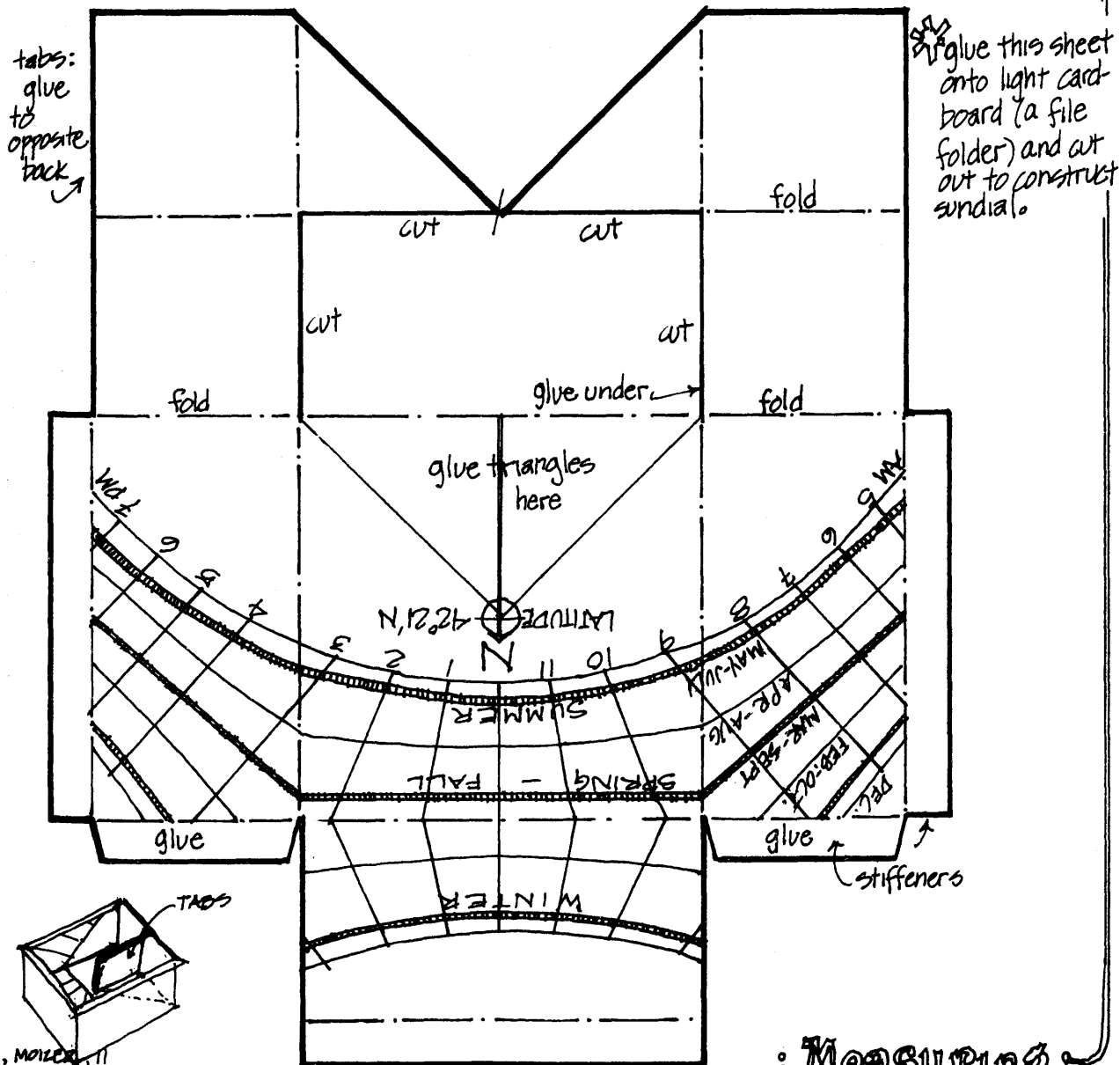


B. DETERMINING THE EFFECTS OF DESIGN SOLUTIONS ON INSOLATION

TO SIMPLY PINPOINT THE LOCATION OF THE SUN, HOWEVER, MAY NOT BE ENOUGH TO DETERMINE THE EFFECT OF LOCAL DESIGN SOLUTIONS ON THE OVERALL RADIATION TO BE RECEIVED BY THE SITE. THE DIRECTION AND ANGLE OF NEW SLOPES AND SURFACES, THE HEIGHT AND FORM OF THE NEW TOPOGRAPHY, AND THE RELATIONSHIPS WITH THE IMMEDIATE SURROUNDINGS, ALL HAVE AN EFFECT ON THE SUN CLIMATE OF THE SITE. SO, WHEREVER MEASUREMENT OF LOCAL RADIATION CONDITIONS CANNOT BE PREDICTED FROM THE GENERAL FACTS, OR FROM SITE VISITS, A MODEL OR A SUNDIAL CAN BE THE MOST USEFUL

A SUNDIAL:

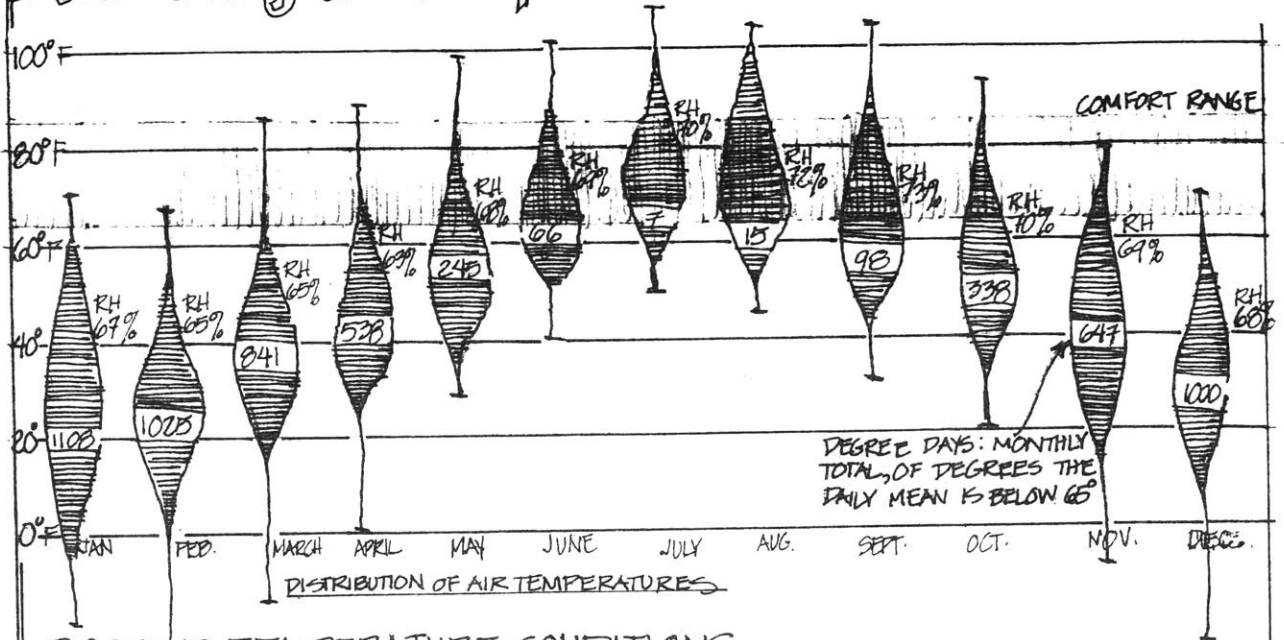
AFTER CONSTRUCTED, ATTACH THE FOLLOWING SUNDIAL TO A MODEL OF THE PROPOSED SITE, WITH THE SUNDIAL ORIENTED TO THE MODEL'S NORTH. PLACE THE MODEL NEAR A NATURAL DAYLIGHT SOURCE (A WINDOW FOR EXAMPLE) OR AT LEAST 10 FEET FROM A VERY BRIGHT ARTIFICIAL LIGHT. PROCEED THEN TO TIP AND TURN THE MODEL AND SUNDIAL COMBINATION, UNTIL THE PEAK OF THE TRIANGLE INDICATES THE RIGHT MONTH AND HOUR TO BE EVALUATED. THE SUNLIGHT IS NOW FALLING ON THE MODEL AS IT WOULD ON THE SITE FOR THAT PARTICULAR TIME. THIS ALLOWS ONE TO VISUALIZE AND DESIGN THE SITE AND BUILDINGS PRECISELY, TO CAPTURE LOW WINTER SUNS, WHEN NEEDED MOST, AND SIMULTANEOUSLY SHIELD FROM THE HIGH SUMMER SUNS.



ref: 1, 7, MODEL, 11

: MEASURING:

Measuring the Temperature



BOSTON'S TEMPERATURE CONDITIONS

IN GENERAL, BOSTON'S DESIGN EMPHASIS CANNOT BE FOR SUMMER CONDITIONS, BECAUSE OF THE FAR GREATER DEMANDS MADE BY THE EIGHT WINTER MONTHS.

BOSTON HAS TWO MONTHS OF OVERHEATED DAYS—JULY AND AUGUST—WHEN THE SUN'S RADIATION DEFINITELY NEEDS TO BE AVOIDED. OF GREATER CONCERN, HOWEVER, OVER 32% OF BOSTON'S DAYS SUFFER UNDER SEVERE WINTER TEMPERATURES, WITH FREQUENT FROSTS AND FREEZE-THAW. TO MAKE MATTERS WORSE, PREVAILING WINDS ARE ALSO AT A PEAK DURING THE WINTER MONTHS. FOR THIS REASON, DESIGN SOLUTIONS SHOULD ORIENT FOR MAXIMUM SOLAR HEAT GAIN, THEN INSULATE WITH HEAT RETAINING SURFACES, AND PREVENT DEVELOPING WIND SPEEDS.

OF BOSTON'S DEGREE DAYS: 780 HRS/YR = AIR CONDITIONING MIGHT BE NEEDED
 1405 HRS/YR = NO HEATING OR COOLING NEEDED
 3050 HRS/YR = LOW HEAT, FIRE PLACE
 2830 HRS/YR = MEDIUM HEAT REQUIRED
 ~ 30° BELOW THE NORM OF 65°F
 710 HRS/YR = CENTRAL HEATING NEEDED
 ~ 50° DAY, BELOW THE NORM OF 65°F

GENERAL TEMPERATURE CONDITIONS:

TEMPERATURE CONDITIONS IN NEW ENGLAND ARE DEFINED IN THREE BASIC CATEGORIES: DRY HEAT, HUMID HEAT, AND LASTLY COLD TEMPERATURE.

AREAS OF DRY HEAT. HOT DRY AREAS ARE CHARACTERIZED BY HIGH DAYTIME TEMPERATURES AND UNCOMFORTABLY LOW NIGHTTIME TEMPERATURES. THIS FLUCTUATION CAN BEST BE MET BY DELAYING THE DISPERSION OF DAYTIME HEAT AS LONG AS POSSIBLE, SO THAT IT WILL WARM THE ATMOSPHERE LATER WHEN IT IS NEEDED MOST. THIS IS ACHIEVED BY USING MATERIALS OF HIGH HEAT CAPACITY WHICH ACT AS A "HEAT SINK", ABSORBING DURING THE DAY AND RERADIATING DURING THE NIGHT.

(continued)

AREAS OF HUMID HEAT. HUMID AND HOT AREAS ARE CHARACTERIZED BY HEAVY RAINFALL, HIGH HUMIDITY, AND TEMPERATURES WITH LITTLE DAILY OR SEASONAL VARIATION EXCEPT FOR THE INTENSE RADIATION. THE DESIGN IMPLICATIONS MIGHT INCLUDE MAXIMIZING SHADING, AND MINIMIZING THE SOIL HEAT CAPACITY (WHICH OFFERS NO ADVANTAGES WHEN THERE IS LITTLE TEMPERATURE VARIATION). ALLOW FOR VENTILATION TO HELP THE AREA LOSE HEAT, BY AN OPENNESS IN THE SITE DESIGN.

COLD AREAS. ALTHOUGH THERE ARE DIFFERENT RANGES OF COLDER TEMPERATURES IN NEW ENGLAND, THE PRINCIPLES FOR REDUCING HEAT EXCHANGE ARE SIMILAR TO THOSE OUTLINED FOR DRY HEAT. PREVENTING THE LOSS (OR GAIN IN SUMMER) INVOLVES MINIMIZING SURFACE AREA, MAXIMIZING HEAVY MATERIALS WITH GOOD INSULATING CAPACITIES, AND PREVENTING THE DRYING WINDS FROM SPEEDING HEAT EXCHANGE. THE MAJOR DIFFERENCE BETWEEN COLD AREAS AND SITES OF DRY HEAT, IS THE NEW DESIRE TO CAPTURE AS MUCH SOLAR RADIATION AS POSSIBLE.

THE DESIGN CRITERIA:

EFFECTIVE TEMPERATURE IS A SENSATION PRODUCED BY THE COMBINED EFFECT OF RADIATION AND AMBIENT TEMPERATURE, RELATIVE HUMIDITY, AND AIR MOVEMENT.

A TEMPERATURE FOR HUMAN COMFORT LIES BETWEEN 65° AND 85° F, AS LONG AS THE RELATIVE HUMIDITY CONTINUES TO LIE BETWEEN 20% AND 50%. LOCAL WIND MOVEMENT ALSO MUST BE MAINTAINED AT LESS THAN 200 FEET PER MINUTE TO PRESERVE THE EFFECTIVE DESIGN TEMPERATURE. THE IDEAL DESIGN TEMPERATURE OF 72° IN THE U.S., HAS RECENTLY BEEN REDUCED TO 68° F, BUT HAS NOT YET REACHED ENGLAND'S DESIGN TEMPERATURE OF 65°.

- AS A RULE, IN NEW ENGLAND,
- ORIENT FOR MAXIMUM SOLAR HEAT GAIN.
 - INSULATE WITH HEAT RETAINING SURFACES.
 - EXTEND PAST THE DANGEROUS FROST LINE AT -2.5 TO -3 FEET.
 - BRAKE THE HIGH WINTER WINDS.

references: 1, 8, 11, 15.

Measuring the Temperature Climate:

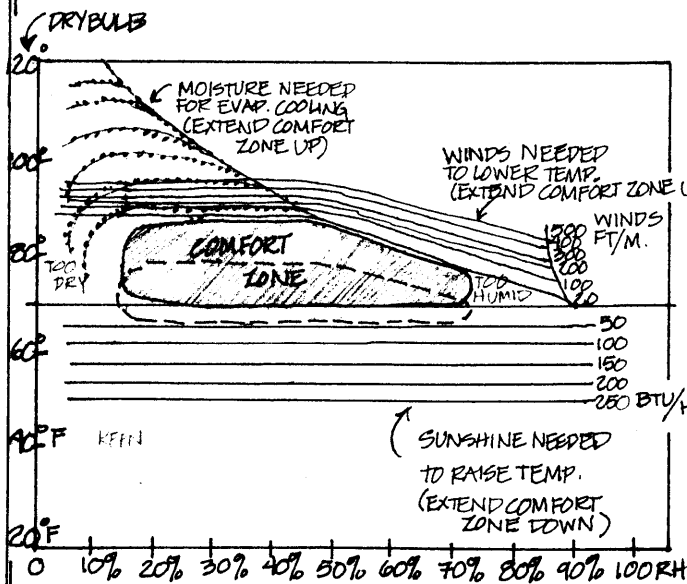
Measuring the Temperature Climate:

DESIGN PHENOMENA : TEMPERATURE & RELATED CONDITIONS

EFFECTIVE TEMPERATURES, MEASURED AT THE SITE, INVOLVE THE INTERRELATION OF THE DRY AIR TEMPERATURES WITH RELATIVE HUMIDITY, RADIATION, AND AIR MOVEMENT. FOR THIS REASON, A SITE WITH UNDESIRABLE TEMPERATURE CONDITIONS CAN OFTEN BE CORRECTED BY VARYING THE LEVELS OF RELATIVE HUMIDITY OR AIR MOVEMENT WHEN NO ADDITIONAL RADIATION OR HEAT IS AVAILABLE.

IN MORE GENERAL TERMS:

- INCREASED HUMIDITY ALLOWS FOR EVAPORATIVE COOLING.
FORTUNATELY, SOME OF THE HEAT OF THE AIR WILL BE NEEDED TO EVAPORATE ANY WATER ADDED TO THE SITE, SINCE THE PHASE CHANGE FROM LIQUID TO VAPOR REQUIRES ENERGY. HOWEVER, THERE IS A LIMIT TO THESE EVAPORATIVE COOLING BENEFITS. ONCE THE SURFACE AIR REACHES A LEVEL NEAR SATURATION, VERY LITTLE ADDITIONAL HEAT CAN BE DRAWN FROM THE HIGH AIR TEMPERATURES TO EVAPORATE MORE MOISTURE, SUCH AS BODY SWEAT, LEAVING OVERHEATED PEOPLE AS A MARK.
- INCREASED WIND VELOCITY REDUCES EFFECTIVE AIR TEMPERATURE.
WINDS DO NOT ACTUALLY AFFECT THE TEMPERATURE OF THE AIR ITSELF, BUT INSTEAD COOL SURFACES BY EVAPORATION, AND BY CAUSING RAPID HEAT TRANSFER (TO PREVENT LONG-RANGE THERMAL RETENTION).
- INCREASED RADIATION EXPOSURE RAISES EFFECTIVE AIR TEMPERATURE.
DIRECT RADIATION COMBINES THE EFFECTS OF: REFLECTED INCIDENT ENERGY AND THE LATER EMISSION OF GROUND STORED HEAT, TO INCREASE THE GIVEN AIR TEMPERATURE. SHADING, ON THE OTHER HAND, CAN LOWER NORMAL SITE TEMPERATURES BY ELIMINATING THIS RADIATION FACTOR.



BIOCLIMATIC CHART.

A SIMPLIFIED VERSION OF THE BIOCLIMATIC CHART SHOWS THE RELATIONSHIP OF THE VARIOUS CLIMATIC ELEMENTS. THE CHART IS BUILT-UP WITH DRY-BULB TEMPERATURE AS ORDINATE, AND RELATIVE HUMIDITY AS ABSCISSA. IN PLOTTING LOCAL TEMPERATURES AND RH., OFTEN THE POINT FALLS OUTSIDE THE COMFORT ZONE, REQUIRING CORRECTIVE MEASURES. AS AN EXAMPLE, AT 75°F AND 70% HUMIDITY, INCREASING WIND SPEED CAN BE EFFECTIVE IN OFFSETTING HIGH TEMPERATURES & HUMIDITY. AT A TEMP. OF 50°F AND HUMIDITY OF 56%, SOME 200 BTU/HR OF RADIATION FROM THE SUN CAN RESTORE COMFORT;

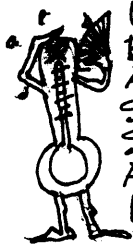
TO MEASURE AND CALCULATE:

THE AIR LAYER NEAR THE GROUND IS VERY DIFFERENT THAN THE AIR IN THE REGION ABOVE THE SITE. THE REGIONAL DESIGN TEMPERATURES GIVEN PREVIOUSLY ARE LOCALLY DEPENDENT ON:

THE SEASON
 THE HOUR OF THE DAY
 THE SLOPE (see topography)
 THE NATURE OF THE TERRAIN (see soils, drainage)
 & THE VEGETATION,

ALL OF WHICH MODIFY THE TEMPERATURE AT THE GROUND LEVEL, AND ARE SOMEWHAT PREDICTABLE BY SITE CLUES.

★ HOWEVER, TO ACTUALLY MEASURE THE LOCAL TEMPERATURE CONDITIONS ON THE SITE:



USE A CALIBRATED THERMOMETER. THIS SHOULD BE PLACED AT THE SAME HEIGHT ABOVE THE GROUND AT EACH STATION, AND SHOULD BE ADDITIONALLY SHIELDED FROM RADIATION AND WINDS. READINGS SHOULD BE MADE AT DIFFERENT TIMES OF THE DAY, AND IN DIFFERENT SEASONS, BEFORE DESIGN IMPLICATIONS ARE DRAWN.

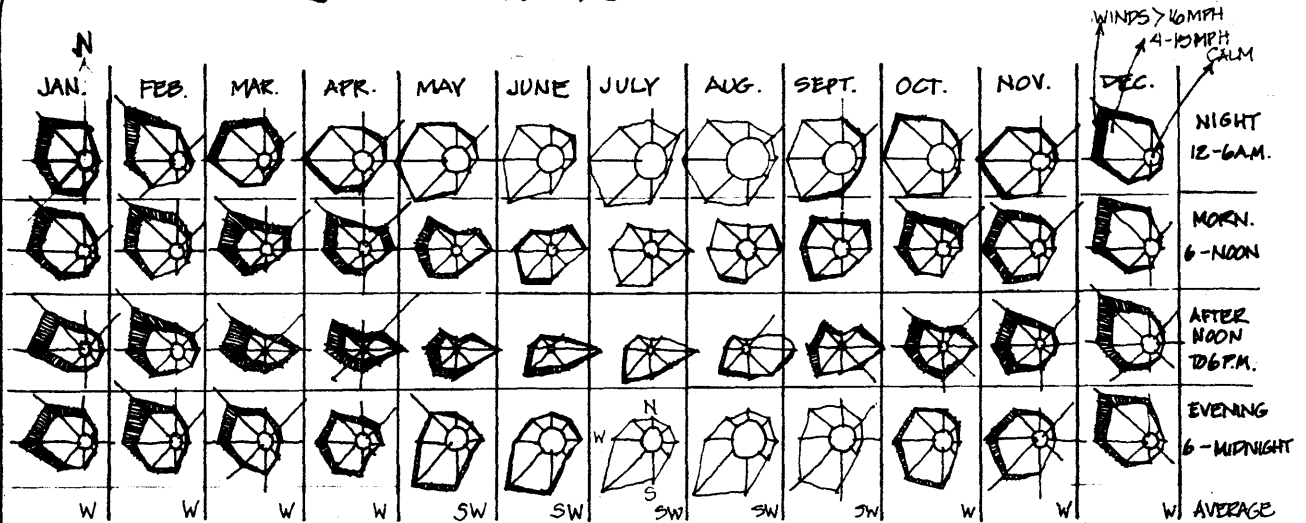
THE SMALL SCALE DEVIATIONS IN CLIMATE PLAY A MAJOR ROLE IN THE PROBLEMS WHICH ARCHITECTS HAVE TO FACE IN SELECTING SITES WITH REGARD TO TEMPERATURE.

P.S. JUST AS EXTREME DRY-BULB TEMPERATURES & WINDS MUST BE AVOIDED, CARE MUST BE TAKEN TO PREVENT EXCESSIVELY HIGH OR LOW RELATIVE HUMIDITY IN BALANCING THE TEMPERATURES, SINCE IT CAUSES CORROSION AND DISCOMFORT:

WET-BULB THERMOMETERS HELP MEASURE HUMIDITY IN THE AIR. A WET MUSLIN BAG IS PLACED OVER THE BULB OF A THERMOMETER. THE WATER IN THE BAG EVAPORATES, AND IN SO DOING REQUIRES HEAT. THIS REDUCES THE TEMPERATURE OF THE BULB TO A POINT, TERMED WET-BULB TEMPERATURE. IT REPRESENTS THE ACTUAL HUMIDITY LEVEL PRESENT, AND THE LOWEST POINT TO WHICH AIR CAN BE COOLED BY EVAPORATING WATER INTO IT AT A CONSTANT PRESSURE.

ref: 1, 5, 7, 8, 11, 10

The Wind Microclimate



BOSTONS WIND CLIMATE

BOSTON IS RELATIVELY WINDY, BECAUSE THE NORMAL WESTERLY WINDS ARE INTENSIFIED BY INDUCED LOW-PRESSURE WINDS OVER THE OCEAN. HOWEVER, CONSIDERABLE LOCAL VARIATION IN WIND DIRECTION AND VELOCITY EXIST, BECAUSE OF IRREGULARITY OF LANDSCAPES.

1. THE COLDEST WINTER WINDS ARE ALMOST UNIQUELY FROM THE NW, IN EVENING, AND SHOULD BE DUFFERED AGAINST SINCE THEY SPEED UP THE AIR EXCHANGE BETWEEN WARMER AREAS AND THE COLDER OUTSIDE. THERE IS LITTLE WINTER WIND FROM THE EAST AND SOUTHEAST.
2. THE HOTTEST PERIODS OF THE SUMMER ARE FACED WITH PURELY SOUTHWEST AND SOUTHERLY WINDS. THE SUMMER AXIS FOR CROSS VENTILATION IS SW-NE, AND SHOULD BE OPENED UP, TO INCREASE EVAPORATION (COOLING PEOPLE & PLACES), AND INCREASE VENTILATION.
3. THE MOST CONFUSED WIND PATTERNS ARE THANKFULLY DURING PERIODS WHEN A BREEZE COULD BE DELIGHTFUL WITH A SWEATER OR NO BREEZE COULD ALSO BE COMFORTABLE.

- AFTERNOONS ARE THE WINDIEST PART OF THE DAY, WHILE EVENINGS AND NIGHT TEND TO BE CALM (MAKING IT HARD TO RID AN AREA OF THE DAYS HEAT ACCUMULATION). MARCH IS THE WINDIEST MONTH, AUGUST THE LEAST WINDY, WITH WINTERS IN GENERAL THE WINDIER SEASON.

WHAT TO LOOK FOR

IN ORDER TO EVALUATE THE SPECIFIC EFFECTS OF WIND ON HUMAN COMFORT, THREE ISSUES MUST BE ANALYZED.

1. PREVAILING WIND DIRECTIONS, BY FREQUENCY PER MONTH
2. AVERAGE WIND SPEED IN MPH (PER DIRECTION)
3. GENERAL CHARACTERISTICS OF THE WIND (I.E. TEMPERATURE)

AN EFFORT MUST BE MADE TO DISTINGUISH DESIRABLE BREEZES FROM UNWANTED WINDS, WITH THE DIRECTIONS AND VELOCITIES IDENTIFIED.

(continued)

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THEN, PARAMETERS MUST BE SET AS TO WHETHER TO MINIMIZE EXISTING WIND SPEEDS ON THE SITE (BY REDIRECTING, SLOWING, OR STOPPING), OR TO MAXIMIZE (BY FUNNELING, SPEEDING, OFFERING LEAST RESISTANCE) WINDS FOR THE RESULTING DESIGN SOLUTION. IN GENERAL,

BEAUFORT NO.	WIND SPEEDS		EFFECT
	M.P.H.	FT/MIN.	
1	0-3	0-40	NOT NOTICEABLE.
2	4-7	40-80	PLEASANT, HARDLY NOTICEABLE.
3	8-12	80-120	PLEASANT, CLOTHING FLAPS.
4	13-18	140-200	RAISES DUST, PAPER. HAIR MUSSED.
5	19-24	200-270	SLIGHTLY, THEN ANNOYINGLY DRAFTY
6	25-31	270-350	UMBRELLAS USED W/DIFFICULTY.
7	32-38	350-425	HARD TO WALK.
8	39-46	425-500	LITTLE PROGRESS IN WALKING.

DESIGN VALUES:

INTERESTINGLY ENOUGH, CALCULATIONS INDICATE THAT THE HEATING LOAD OF AN UNPROTECTED BUILDING SUBJECT TO 20 MPH WINDS IS 2.4 TIMES GREATER THAN IF THE BUILDING (OR SITE) WERE SUBJECTED ONLY TO 5 MPH WINDS.

WHY SLOW THE WIND?

- PREVENT STRUCTURAL DAMAGE FROM HIGH WINDS OF BUILDING, TREES, SOIL.
 - REDUCE DESSICATION BY DRY WINDS, WHICH DRY OUT ANYTHING MOIST.
 - REDUCE WIND EROSION AND POLLUTION DISPERSION.
 - LESSEN THE CHILL OF COLD WINDS WHICH REMOVES HEAT FROM WARM SURFACES.
 - CREATE A PROTECTED 'WIND SHADOW' AREA BY BLOCKING.
- ↳ WHEN COLD & DRY

WHY SPEED THE WIND?

- INCREASE EVAPORATION AND DRYING IN HIGH HUMIDITY OR DAMP GROUND.
 - INCREASE THE RATE OF THERMAL EXCHANGE, TO PROMOTE COOLING IN SUMMER, OR WARMING TRANSFER.
 - AS A SOURCE OF POWER.
 - TO PROVIDE THE AIR CHANGE NECESSARY FOR HUMAN HEALTH; REPLENISHING OXYGEN.
- ↳ WHEN HOT & HUMID

SUPPOSE ONE WANTS TO CATCH THE WIND IN THE SLEEPING AREAS AT NIGHT DURING THE SUMMER? WHERE IS THE BREEZE GOING TO BE COMING FROM, AND HOW FAST?

The Wind Microclimate:

PREDICTING LOCAL WINDS:

SPECIFIC SITES MUST BE STUDIED FOR THEIR LOCAL TOPOGRAPHIES AND LANDSCAPES, SINCE THE MICROCLIMATE VARIATIONS CAN ACCOUNT FOR GREAT CHANGES IN PREVAILING WIND DIRECTION AND SPEED. FIRST OF ALL, ONE NEEDS TO ESTABLISH THE PATTERN OF WIND FLOW EXPECTED, - THE REGIONAL WIND DIRECTION AND SPEED, THEN, TO PREDICT THE POTENTIAL ZONE OF EDDIES AND THE DISTRIBUTION OF LOCAL PRESSURES WHICH MAY AFFECT THIS WIND PATTERN.

IN GENERAL, THE PREDICTABLE REVERSALS OR VARIATIONS IN PREVAILING WIND DIRECTIONS AND SPEEDS MIGHT BE CAUSED BY:

A. POTENTIAL ZONES OF EDDIES:

- 1) SURFACE FRICTION ESTABLISHED BY ROUGH SURFACES WILL HOLD A LAYER OF AIR AT THE GROUND SURFACE, SLOWING AND ELEVATING WINDS.
- 2) NATURAL AND MANMADE BARRIERS BLOCK, INDUCE, OR SLOW PREVAILING WIND MOVEMENT AND ESTABLISH NEW PATTERNS OF WIND FLOW. SINCE MOST SITE WORK WILL FALL INTO THIS CATEGORY, IT SHOULD BE DEALT WITH MORE THOROUGHLY.

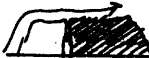
✦ AS THE LENGTH OF A WIND BARRIER INCREASES ACROSS THE PATH OF THE WIND, SO DOES THE DEPTH AND LENGTH OF THE PROTECTED EDDY ZONE.



✦ AS THE HEIGHT OF A LANDFORM INCREASES, MUCH MORE AIR IS FORCED TO GO AROUND THE BARRIER (WITH LITTLE ADDITIONAL AIR GOING OVER!).



✦ AS THE SLOPE (OR PITCH) OF A BARRIER INCREASES, SO DOES THE HEIGHT AND DEPTH OF THE EDDY. THE MORE DRAMATIC THE DIRECTION SHIFT, THE HARDER IT IS FOR THE WIND TO RETURN TO THE ORIGINAL DIRECTION, OFTEN LEAVING NO-PRESSURE AREAS (INSTEAD OF EDDIES).



✦ AS THE DEPTH OF THE BARRIER INCREASES, THE LONGER THE NEW WIND DIRECTION HAS BEEN ESTABLISHED, AND THE LONGER IT WILL HOLD - LEAVING LONGER PROTECTED AREAS DOWNWIND.

IN GENERAL, A LOCAL EDDY ALLOWS THE PREVAILING WIND TO MAINTAIN ITS DIRECTION BY QUIETLY FILLING AREAS WHERE WIND IS EXPECTED.

B. DISTRIBUTION OF LOCAL PRESSURES:



- 1) BARRIERS ALSO CREATE PRESSURE DIFFERENTIALS WHICH INDUCE WIND MOVEMENT. WHEN THERE IS A PRESSURE GRADIENT, WINDS WILL ALWAYS GO TO THE LOW PRESSURE POCKETS TO EQUALIZE CONDITIONS.

○ WHENEVER THERE ARE OPENINGS IN A BARRIER, FOR INSTANCE, AIR FLOW WHICH GENERALLY SQUEEZES THROUGH OPENINGS NORMAL TO ITS DIRECTION, WILL NOW ALSO SEEK OPENINGS TANGENTIAL TO ITS FLOW! THE WIND CAN BE PULLED IN UNEXPECTEDLY BY PROJECTIONS FROM THE TANGENTIAL SURFACE, AND BY LOW PRESSURE POCKETS WITHIN SEEKING A PRESSURE EQUALIZATION.



- 2) WHEN THE SUN WARMS CERTAIN SPOTS OF THE EARTH MORE THAN OTHERS, A TEMPERATURE DIFFERENCE GIVES RISE TO UNEQUAL PRESSURES AND INDUCED WINDS.
 - ONE GOOD EXAMPLE OF THIS IS THE VARIABILITY OF SLOPE-AND-VALLEY WINDS (WHERE WIND DIRECTIONS AND SPEEDS CHANGE CONSTANTLY WITH THE HEAT AND RADIATION RECEIVED. ANOTHER EXAMPLE IS THE DIFFERING THERMAL CAPACITY OF SOILS, ESPECIALLY IN THE CASE OF WATER FROM WHICH INDUCED BREEZES CAN REVERSE, NEUTRALIZE, OR ADD TO PREVAILING WINDS.

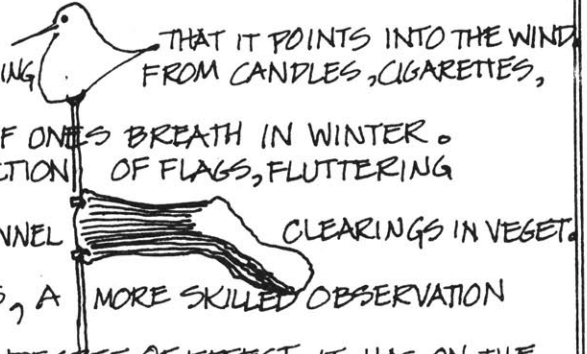
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CALIBRATIONS:

DUE TO THE INACCURACY OF PREDICTING LOCAL WIND SPEEDS & DIRECTIONS BY GENERAL PRINCIPLES, IT MAY BE USEFUL TO OBTAIN DIRECT DATA FROM THE SITE AND FROM A SCALE MODEL.

TO IDENTIFY THE PREVAILING WIND DIRECTION FOR A PARTICULAR TIME AND IN A PARTICULAR AREA ON THE SITE, SIMPLE METHODS ARE OFTEN BEST:

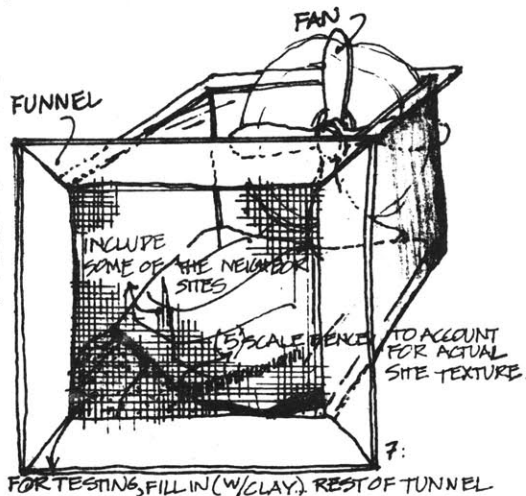
- 1) THE USE OF A WIND VANE (NOTE
- 2) THE OBSERVATION OF SMOKE, STREAMING FROM CANDLES, CIGARETTES, INCENSE STICKS ...
- 3) THE OBSERVATION OF THE VAPOR OF ONE'S BREATH IN WINTER.
- 4) THE OBSERVATION OF THE DIRECTION OF FLAGS, FLUTTERING TREE LEAVES, WIND SOCKS.
- 5) EVIDENCE OF WIND SHEAR AND CHANNEL CLEARINGS IN VEGET.



TO IDENTIFY THE PREVAILING WIND SPEEDS, A MORE SKILLED OBSERVATION IS NEEDED, TO ESTIMATE:

THE FORCE OF THE WIND FROM THE DEGREE OF EFFECT IT HAS ON THE WIND SOCK, OR FLAGS, OR SMOKE.

ALTHOUGH ON-SITE TESTING CAN BE USEFUL TO GIVE A CLEAR UNDERSTANDING OF THE EXISTING LOCAL CONDITIONS, IT CANNOT EFFECTIVELY PREDICT THE NEW CONDITIONS WHICH WILL RESULT FROM THE DESIGN SOLUTION. FOR THIS REASON, IT BECOMES IMPERATIVE TO RESEARCH THE POTENTIAL PATTERN OF WIND MOVEMENT, BY A SCALE MODEL.

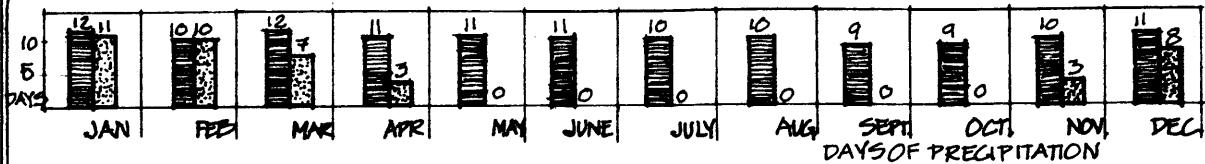
A CRUDE WIND TUNNEL

PREDICT THE GENERAL PATTERN OF WIND MOVEMENT: WIND DIRECTION, AREAS OF CALM OR GUSTINESS, SPREADING, BLOCKING OR CHANNELLING OF AIR FLOW.

MAKE A RECTANGULAR BOX OPEN AT BOTH ENDS AND LARGE ENOUGH TO CONTAIN THE SITE MODEL AT VARIOUS WIND TESTING ANGLES. OVER ONE END OF THE BOX, PLACE A FINE SCREEN AND ATTACH A FUNNEL FRAME TO EASE INTAKE. TO THE OTHER END, ATTACH A LARGE FAN, THAT WILL DRAW AIR THROUGH THE BOX. HAVE THE TOP OF THE BOX TRANSPARENT PLASTIC OR GLASS. BY INTRODUCING SMOKE THROUGH THE FUNNEL, FROM A CIGAR OR INCENSE BURNER, THE STREAMLINES OF THE SMOKE WILL MAKE THE GENERAL WIND PATTERNS CLEARLY VISIBLE. THE AIRFLOW CAN BE STUDIED IN GREATER DETAIL BY MEANS OF A FINE WHITE THREAD TIED TO THE END OF A ROD. AS THIS 'PENNANT' IS MOVED ABOUT IN THE MODEL SPACE IT WILL MAKE THE LOCAL AIR FLOW VISIBLE AS IT STREAMS OUT, DROOPS, FLUTTERS, FLIES AT AN ANGLE OR BACKWARDS. TEST THE MODEL AT DIFFERENT ANGLES - FOR THE DIFFERENT PREVAILING WIND DIRECTIONS.

: The Wind Microclimate:

The Precipitation Microclimate:



PRECIPITATION IN BOSTON

THE AVERAGE ANNUAL RAINFALL IN BOSTON IS ABOUT 43 INCHES RATHER UNIFORMLY DISTRIBUTED THROUGHOUT THE YEAR. LATE SPRING AND FALL TEND TO HAVE LESS RAIN THAN WINTER AND SUMMER. RAINS ARE GENERALLY HEAVY AND BRIEF IN SUMMER, WHILE LONG AND LIGHT IN WINTER. THERE IS ALSO LESS EVAPORATION IN WINTER, CREATING SUSTAINED MUDDY CONDITIONS. THE AVERAGE SNOWFALL IN A YEAR IS ALSO ABOUT 43". JANUARY AND FEBRUARY RECEIVE ABOUT 12 INCHES EACH, AND TENDS TO ACCUMULATE OVER THE MONTH. DECEMBER AND MARCH SNOWFALL IS LIGHTER AND DOES NOT ACCUMULATE.

THERE ARE BASICALLY FIVE TYPES OF PRECIPITATION WHICH MUST BE RECOGNIZED: RAIN, SNOW, HAIL, SLEET, AND FOG.

- IT IS DIFFICULT TO DESIGN RESPONSIVELY TO HAIL, SLEET OR FOG, EXCEPT TO NOTE THEIR EROSION DAMAGE THEY MAY CAUSE, AND PROVIDE MATERIALS THAT ARE RESISTIVE ENOUGH.
- RAIN AND SNOW, HOWEVER, HAVE BOTH ADVANTAGES AND DISADVANTAGES WHICH CAN BE DESIGNED FOR:
 - ✦ RAIN WASHES AWAY POLLUTION AND DIRT TO CLEAN AIR AND SOILS; IF PROPERLY HANDLED, RAIN IRRIGATES AND PROVIDES A WATER SUPPLY; AND RAIN COOLS AREAS BY CHANGING STATE QUICKLY.
 - ✦ UNFORTUNATELY, RAIN ALSO CAUSES EXCESSIVE DAMPNESS, EROSION AND FLOODING ON THE SURFACE; AN ARTIFICIALLY HIGH WATER TABLE (ESPECIALLY ON FROZEN SUBSTRATA), AND CORROSION THROUGH WET-DRY CYCLES.
 - WHILE IN SOME AREAS SNOW PILE-UP CAN BE IRRITATING AND DAMAGING, GENERALLY THE ACCUMULATION OF SNOW WILL INSULATE THE GROUND AND VEGETATION, PREVENTING FROST AND RAPID HEAT LOSS.

VARIATIONS AT THE LOCAL LEVEL

MOUNTAINS ARE CONDUCIVE TO THE PRODUCTION OF PRECIPITATION BECAUSE IN FORCING AIR TO RISE, IT IS COOLED ADIABATICALLY (LOSING TEMPERATURE WITH HEIGHT) AND IS FORCED TO RELEASE SOME OF ITS VAPOR AS RAIN. SO AT A REGIONAL LEVEL, 1) THE WINDWARD SIDE OF MOUNTAIN RANGES ARE NORMALLY THE WETTEST; 2) PRECIPITATION INCREASES WITH ALTITUDE; AND 3) RAINFALL IS GREATEST IN SUMMER WHEN THE AIR CAN BE SUDDENLY COOLED.

ON A LOCAL LEVEL, HOWEVER, WHERE WIND VELOCITY IS GREATEST, THERE IS A RELATIVELY LIGHT FALL OF PRECIPITATION, MAKING THE WINDWARD SIDE OF SLOPES DRIER, EXACTLY THE REVERSE OF THE CONDITIONS ON MOUNTAIN RANGES. IN GENERAL, THE DISTRIBUTION OF PRECIPITATION IS PARTLY GOVERNED BY AIR SPEED AND DIRECTION.

THE DESIGN IMPLICATIONS: RAIN

SITING WITH REGARD TO PRECIPITATION SHOULD BE BASED ON THE SLOPE OF THE LAND, THE PREVAILING WIND AND THE SUN.

★ THE BUILDING SHOULD NOT BE PLACED ON A SLOPE THAT SUPPORTS THE EXCESS WATER AS DAMAGING RUNOFF, WITHOUT PROVIDING ADEQUATE DRAINAGE COURSES AND MOISTURE-PROOFED FOUNDATIONS.

★ SINCE THE WIND AND THE SUN ARE AGENCIES FOR EVAPORATION, IT COULD BE PARTICULARLY IMPORTANT TO SITE IN RESPONSE TO THEM. THIS IMPLIES AVOIDING THE WIND AND SUN ON HOT SUMMER DAYS WHEN THE MOISTURE IS DESIRABLE FOR AIR COOLING, AND DESIGNING FOR THEM DURING EARLY WINTER MORNINGS TO PREVENT FROST.

THE DESIGN IMPLICATIONS: SNOW

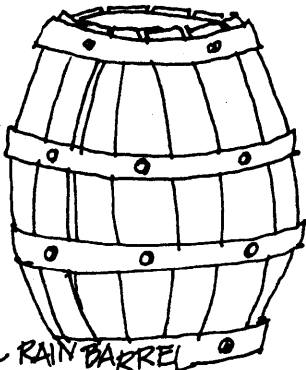
★ THROUGH THE USE OF SNOW FENCES, HEAT RETAINING SURFACES AND PROTECTIVE VEGETATION, ONE CAN PREVENT SNOW ACCUMULATION IN AREAS WHERE NEEDED (PATHS, ROADS..).

★ ELSEWHERE, IT IS DESIRABLE TO PRESERVE AS MUCH SNOW AS POSSIBLE AS AN INSULATOR. ONE FOOT OF SNOW IS MORE EFFECTIVE THAN TWO FEET OF SOIL AND EVEN GREATER DEPTHS OF ROCK FOR PREVENTING HEAT LOSS. A SNOW BLANKET ALSO SAVES THE SOIL FROM BEING FROZEN TO GREAT DEPTHS. (A MAXIMUM SNOW LOAD DOES NOT EXCEED 25 PSF, AND IS TYPICALLY UNDER 10 PSF).

SNOW AS A CLUE:

SNOW IS FORMED IN THE UPPER LEVELS OF THE ATMOSPHERE, INDEPENDENT OF MICROCLIMATES. AS SOON AS THE SNOW SETTLES, HOWEVER, THE INFLUENCES OF LOCAL RADIATION, WIND, GROUND TEMPERATURE, AND SMALL MICROCLIMATE DIFFERENCES MAKE THEMSELVES FELT, MORE SO IN THICK SNOW COVER. OVER SOILS OF GOOD CONDUCTIVITY, THE FLOW OF HEAT FROM BELOW QUICKLY MELTS THE SNOW (OR HEATS POTENTIAL PLACES). WINDS CAUSE SHIFTS IN SNOW THICKNESSES, ALLOWING SNOW TO COLLECT IN FROST POCKETS & NEAR WINDBREAKS BUT SWEEPING SNOW FROM THE WINDIER SITE CHOICES. ON SLOPES WHICH RECEIVE THE MAXIMUM SUNLIGHT, THE SOLAR RADIATION HEATS AND MELTS THE SNOW.

CALIBRATIONS



YE 'OL RAIN BARREL

THE TRADITIONAL RAIN BARREL IS PROBABLY THE CLEAREST INDICATION OF PRECIPITATION CONDITIONS ON THE SITE. RAIN GAUGES

MUST BE PLACED SO WIND (AND EVAPORATION) DOES NOT AFFECT IT. A WINDWARD INCLINE WILL RECEIVE MUCH MORE RAIN THAN A FLAT SHELTERED AREA.

QUESTIONS OF RUNOFF AND DRAINAGE MUST BE DEALT WITH BY OBSERVATION AND MORE EXTENSIVE PROFESSIONAL TESTING.

A PROMISE

Site Reconnaissance is only a small factor in the way that natural forces affect the craft of building. Indeed, in spite of beginning well, one can nullify all the natural gains of responsive site design, by poor building placement, poor designing, or poor detailing. This handbook, then, is the first segment of a projected work on Natural Forces and The Craft of Building, which will eventually encompass all of the following topics:

NATURE AND THE BUILDING SITE: SITE RECONNAISSANCE

- Reading the Site: Vegetation
- Reading the Site: Drainage
- Reading the Site: Topography
- Reading the Site: Soils
- Microclimate Specifics

NATURE AND BUILDING FORM

- Orientation/Siting
- Massing/Shape
- Configuration/Plan
- Massing Additives: balconies, arcades..
- Siting Whoopdedoos: fountains, furniture..

NATURE AND THE BUILDING SHELL

- The Structural System
- Floor sections: crawl spaces, basements, on-grade
- Floors: materials
- Wall sections
- Walls: materials
- Roof sections: attics, slopes, roof forms
- Roofs: materials
- Thermal mass and section variations
- Weathering and the building shell

NATURE AND BUILDING COMPONENTS

- Openings in the building wall
- The choice in windows, size, shape, flexibility
- Strategies for selection and placement
- Shades, Awnings and Screens
- Entrance prototypes
- Window and Door detailing
- Craftsmanship/ Construcion techniques
- Surface finishes: texture, porosity, endurance
- Chimney design: a collection of sound principles.

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With time and practice and interest, the material covered in this thesis will lose its novelty, and the design clues and implications will prove only to be the first step in designing with the natural forces. To continue into the next few chapters, the issues of 'Building Shell' and 'Building Component', a few references might include:

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Prof. Waclaw Zalewski
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*with love to,
Stephannie, Denny, John, Peter, John,
for every last hour.*