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WSEO
WASHINGTON STATE ENERGY OFFICE
Washington Energy Extension Service

Home Conservation

Wise Use of Resources Through Education

Performing the Solar Site Survey:

It is essential to obtain a reasonably accurate assessment of the amount of solar energy available to a given location during the useful life of a potential solar energy investment. It is possible to hire someone to do this for you and it is also possible to do it yourself.

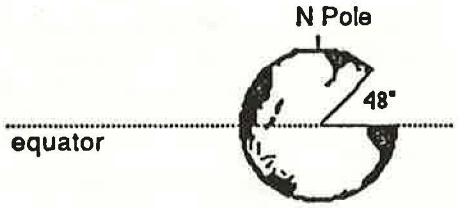
Two things limit the amount of energy available from a given solar technology:

- The technology's efficiency at converting sunlight into the desired form of energy, such as electricity or heat for the home; and
- The amount of energy available from the sun.

This Publication will discuss those factors affecting the amount of solar energy available to a particular location.

The amount of solar energy delivered to a particular site is a function of three things:

- The site's latitude:
- The site's climate; and
- The site's geometry.



Washington's latitude is about 48°N. It is measured as the angle between the plane of the equator and a line drawn from the center of the earth to the Washington portion of the earth's surface.

Figure 1: Latitude

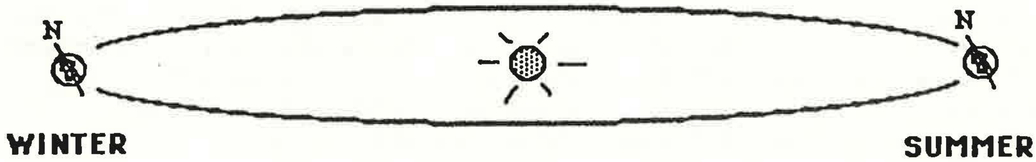


Figure 2. Tile of Earth's Axis of Spin

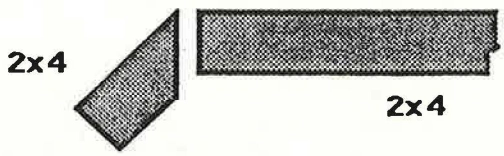


Figure 3. Relation Between Angle and Intensity

Latitude sets the first limits on the amount of solar energy that is available seasonally. The earth orbits around the sun at a constant tilt and the result is that the sun's radiation strikes Washington at a much smaller angle in winter than in summer. Though the earth is slightly closer to the sun in winter it makes little difference. It's the tilt that determines winter's cold and summer's heat. This can be visualized by imagining two 2x4 pieces of lumber, one cut at a right angle and one cut at a 45° angle. Anyone

WEES Seattle Office
914 East Jefferson #300
Seattle, WA 98122-5399
(206) 296-5640

WEES Spokane Office
N. 1212 Washington St., #106
Spokane, WA 99201-2401
(509) 456-6150

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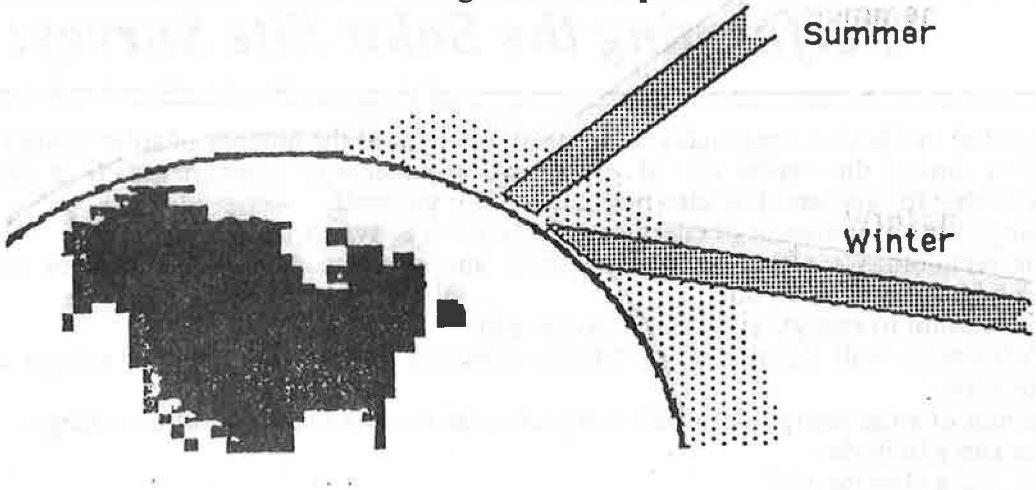
Figure 4. Solar Intensity Varies With Angle and Length of Path Through the Atmosphere.



attempting to fit the two ends would find the 45° cut has a much larger surface area though the board's size is the same. The intensity of a given "beam" of solar radiation is practically constant but when that beam strikes at a small angle it is spread out over a much larger area. A second aspect of latitude is that the sun's radiation must travel a longer path through the atmosphere at the smaller angles; consequently more energy is absorbed and scattered before arriving at the surface.

A third aspect of latitude is its effect on the length of day. The greater the latitude, the shorter the length of day in winter, and lesser the amount of time solar energy is available.

So latitude affects both the intensity of solar energy and the amount of time it is available. These are the two impacts of latitude and measurements of radiation data can account for them.

- The site's climate:

Climate factors impacting the amount of available solar radiation are more readily understandable because we directly experience them as intermittent clouds, dust, fog, and smog. We know they have a tremendous impact on both the seasonal and day-to-day amount of solar radiation delivered to a site. Measurements of incident solar radiation -- insolation -- on horizontal surfaces at ground level are available for a number of U.S. locations. Calculations (based on this data) of the available average monthly insolation for surfaces of different angles from the horizon are available for a number of locations in Washington.

- The site's geometry:

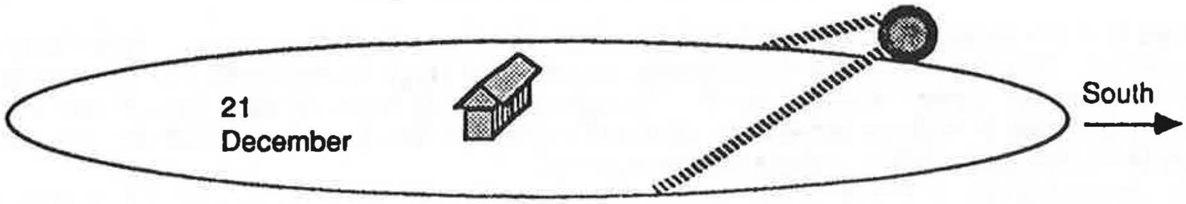
A number of phenomena specific to a given site can impact the amount of available solar energy by direct obstruction. Mountains, trees, and existing buildings are the obvious obstacles, but potential buildings and trees must be taken into consideration, as well as limitations regarding acceptable orientations of a solar structure -- such as a passive solar home that must face the street.

This information can only be obtained by measurement at the site; hence the necessity of a solar site survey. When information obtained from the solar site survey is integrated with latitude and climate data, you will be able to complete your assessment of the amount of solar energy that will arrive at a given location during the useful life of a potential solar energy investment. The remainder of this publication is a guide to completing a solar site survey.

GRAPHING THE SUN PATHS

The sun path across the sky is a function of two things: the earth's daily spin and its annual orbit about the sun. On December 21 the sun path is at its lowest altitude and of shortest duration.

Figure 5. Lowest Winter Sun Path



As summer approaches, the sun path gets higher and of longer duration until it peaks on June 21, when the sun path attains its highest altitude at noon of that day, the longest day of the year.

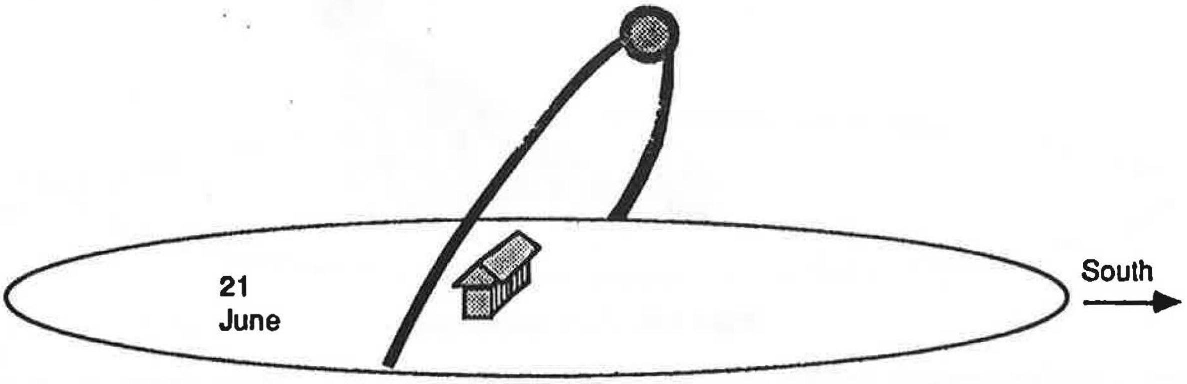


Figure 6. Lowest Summer Sun Path

After June the sun path gets increasingly lower and the days increasingly shorter until the cycle is completed on December 21 and begins all over again.

If we face south we can visualize the paths that the sun would follow on the 21st day of four months of the year and begin to generate a graphic representation of the sun's various positions in the sky.

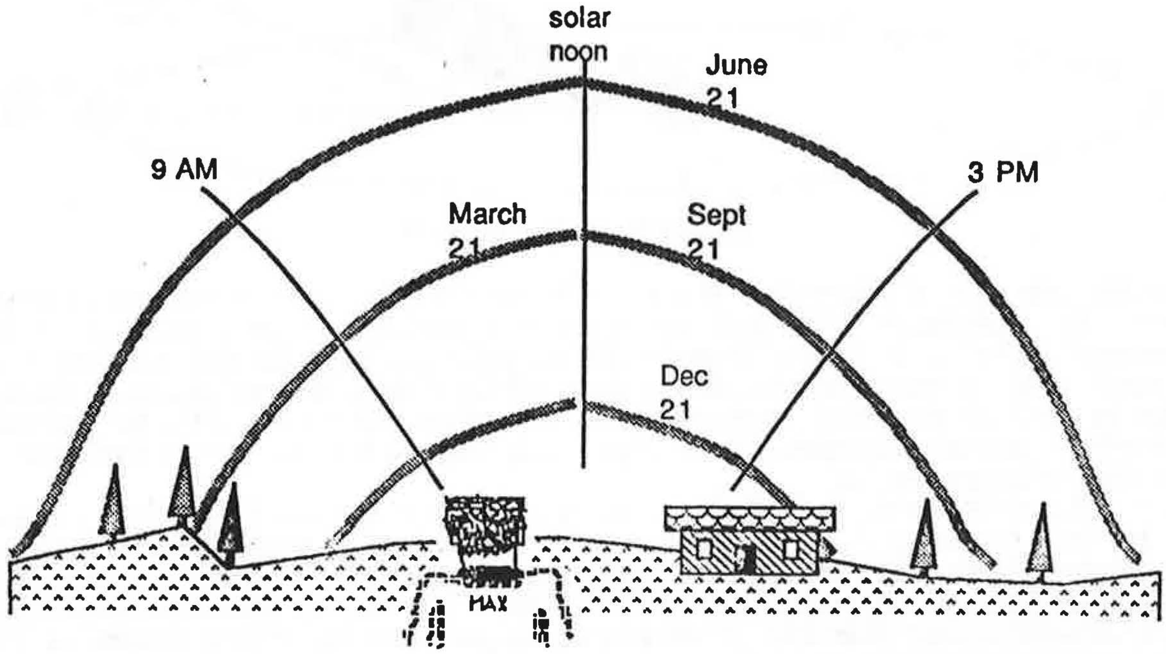


Figure 7. Four Specific Sun Paths

Note that due to the symmetry of the earth's orbit, the sun path of September 21 is the same as that for March 21. This holds true for other months as well (see graph in Appendix 1). The sun is always highest at solar noon when it is due south. Though solar noon is not usually "clock" noon it always marks the time that is midway between sunrise and sunset. Notice, too, that we can represent the sun's position for 9 AM and 3 PM -- or any other time of day.

By measuring the position of the sun at each hour for the 21st day of the 12 months we can completely graph sun paths for any latitude. Sun path charts are exactly such graphs. They were developed simply by measuring the sun's position at the appropriate time.

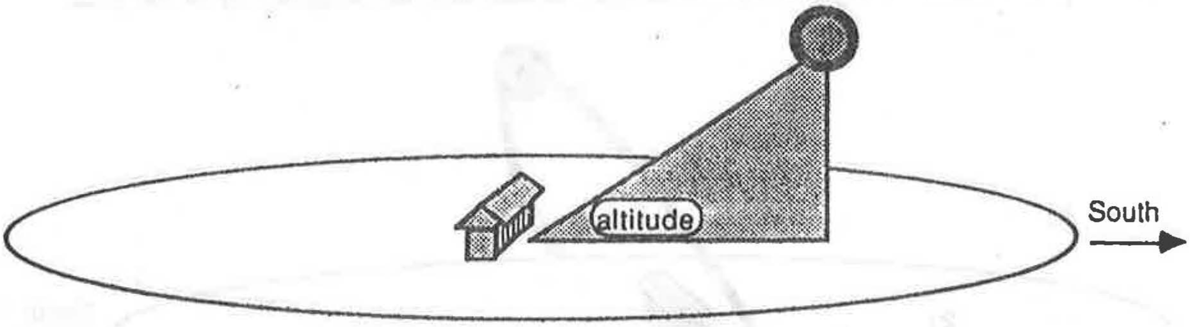


Figure 8. Altitude Angle

Only two measurements are necessary to characterize the sun's sky position at any given moment. We need to know the altitude angle, which is a measure of the sun's height above the horizon. We also need to know the azimuth angle, a measure of how far east or west of true south the measured position lies.

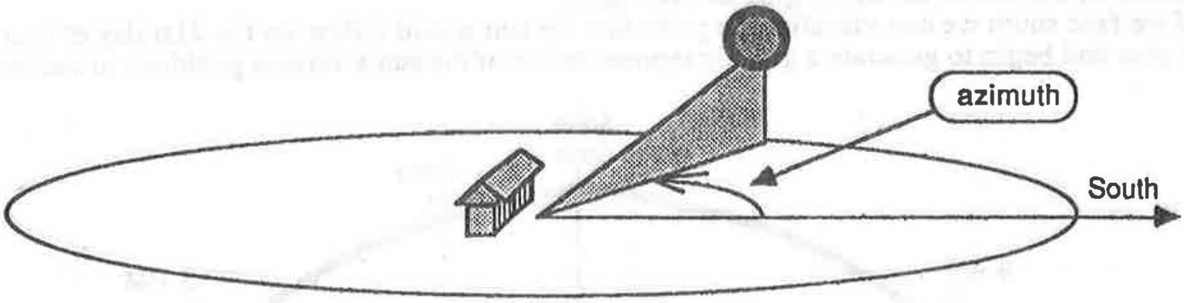
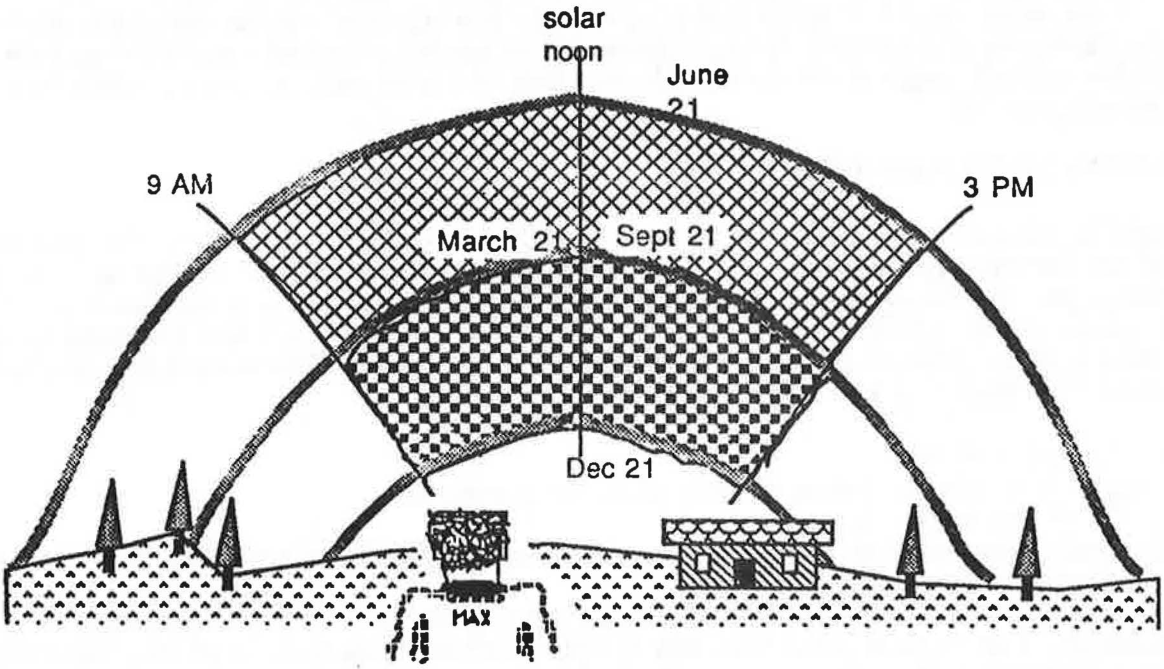


Figure 9. Azimuth Angle

The sun path chart in Appendix 1 is a complete sun chart for 48°N latitude, which is generally appropriate for Washington. Sun path charts are often available in solar design manuals in 4° increments(40°N, 44°N, 48°N, etc.). Note that this sun path chart labels the angles to the east and west of true south along the bottom, and the altitude angles are listed along the vertical axis on the right side. Note that we could use these scales to plot on the sun chart the position of any object for which we know both the altitude and azimuth angles. This is a good time to take a few moments to familiarize yourself with the chart before proceeding.

Note in Figure 10 that the checkered area represents all hours between 9 AM and 3 PM during the six months from September 21 to March 21, roughly the six heating season months. More than 90 percent of the available heating season solar energy passes through this "window". Passive solar homes and other solar space heating applications need to be concerned with this portion of the sun path chart. If we are interested in solar water heating, wherein we can use the energy all year, then the solar window would be expanded to include the cross hatched area as well.

Figure 10. Choosing the Appropriate Solar Window



FINDING TRUE SOUTH

It is important to realize that true south and magnetic south are not the same. In fact they are 21° apart in Eastern Washington and 22° apart in Western Washington. There are a number of ways to locate true south.

Probably the compass is the most well known but may not always be reliable. Local disturbances in the earth's magnetic field can be created by ore deposits in the ground and possibly by large electrical powerlines. Using a compass near metal objects can also impair accuracy of the compass. When accurate, the needle of the compass will point to magnetic north. When looking down at the compass true north will be 21° or 22° counter-clockwise from magnetic north. Also true south will be counter-clockwise from magnetic south.

There is a simple and reliable method using a watch and plumb line. Simply obtain sunrise and sunset times from evening news weather report or the newspaper. Count the number of hours and minutes between sunrise and sunset and divide by two. Add the result to the sunrise time and you have the time at which solar noon occurs. The shadow of a plumb pole or line on level ground is a true north/south line at solar noon. You need only set up the plumb line at the correct time and mark the shadow. One limitation is that you need a sunny day to see the shadow.

ROUGHING IN SOME PRELIMINARY ESTIMATIONS

Sometimes one has some flexibility with regard to the precise location of a solar application, as for example, selection of house sites on a small acreage. In lieu of doing a sun chart for each site it may be possible to reduce the possible alternatives in the following "quick and dirty" manner.

Three fists (knuckles vertical, arms extended) above the horizon (level) is about the sun's height at noon December 21. After finding south you can walk around and "eyeball" potential obstructions. Stay away from obstructions within 45° of south by a distance equal to about 3 times their height. If you can't measure the height of a nearby obstruction, sight its altitude angle with a protractor and weighted string (see below). If the obstruction is due south its angle should be less than about 20° to avoid any shading on December 21. If it is S.E. or S.W. its angle should be less than 7°-10°.

If this exercise gives you a clear indication that a given location will work best, then do the sun chart. If not, make your best guess and pick the spot that represents the center of the south glazing. Pace the distance to obstructions. Roughly determine the angle between true south and each obstruction. This is the azimuth angle (instructions below). You can then refer to the sun chart to locate the obstruction's position.

LOCATING THE OBSTRUCTIONS ON THE SUN PATH CHART

Your goal is to locate each obstruction and plot its position on the sun path chart. You need to site the obstructions from the proposed solar collector site in order to determine each altitude and azimuth angle from that point. You can generally work from the center of the collector area, but in some cases it may be appropriate to site easterly obstructions from the east end of the collector area and westerly ones from the west end. If the collector is to be on a hard to access roof it is possible to work from the ground and mathematically adjust (see references).

- Set up a work area:

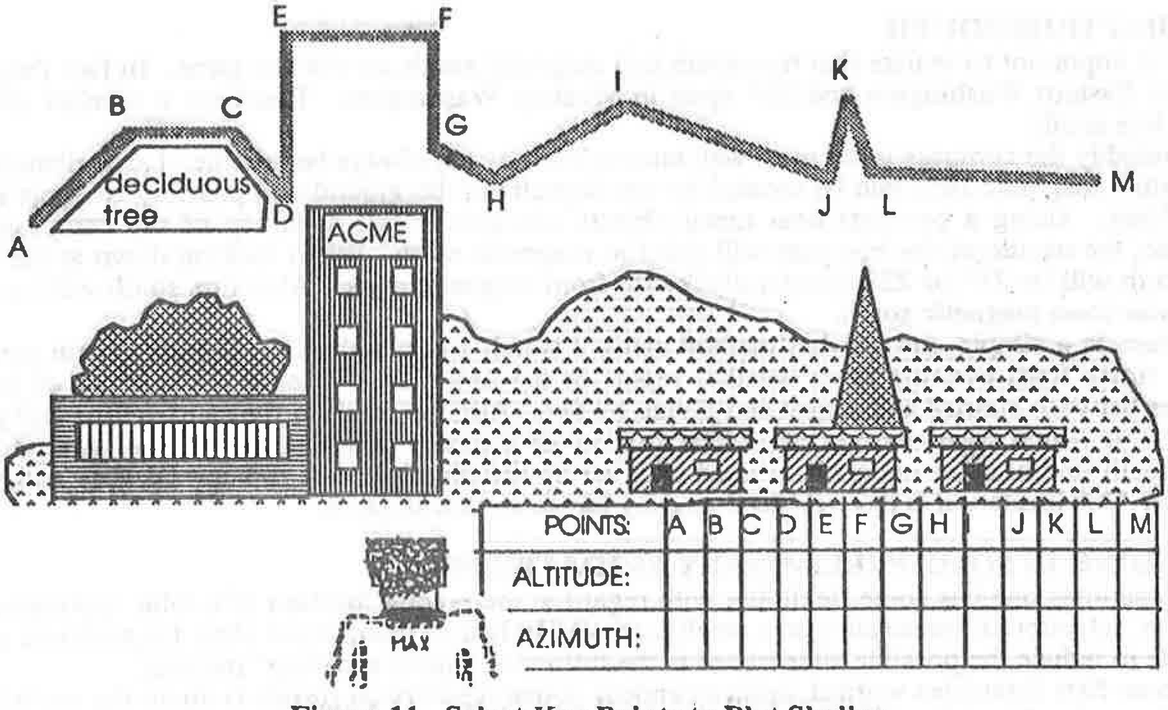
Set up a level table on sawhorses, a stump,on the ground, etc.

- Determine true south:

This needs to be done only once so do it carefully and accurately. Mark it on your work surface.

- Select major obstacle points:

The idea is to plot the skyline. Look for major geometrical points that you can simply draw straight lines between. List them in order from left to right or whatever (a,b,c,d,...) so you can easily record altitude and azimuth angles. Make note of deciduous tree locations as they will warrant special attention later.



POINTS:	A	B	C	D	E	F	G	H	I	J	K	L	M
ALTITUDE:													
AZIMUTH:													

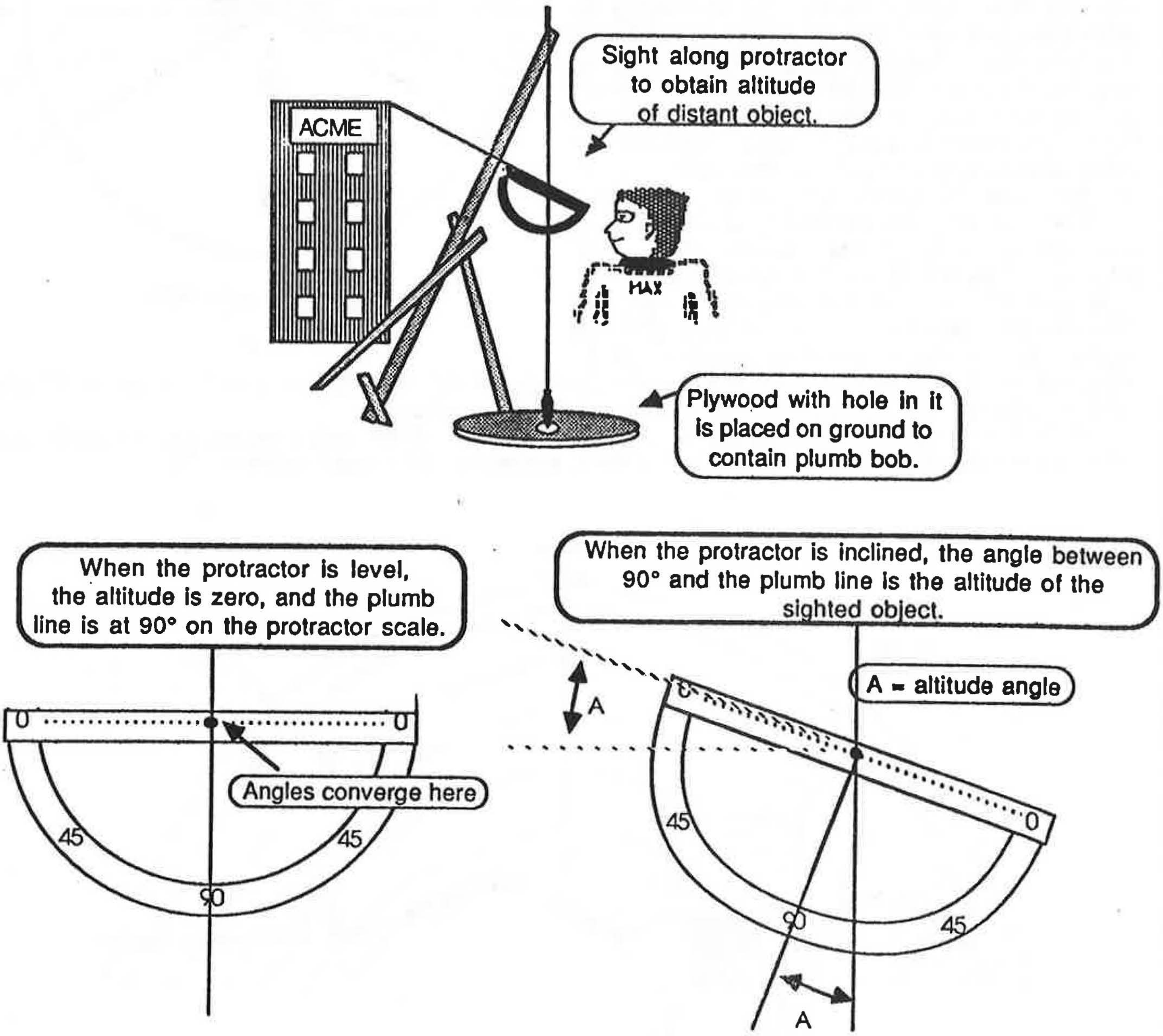
Figure 11. Select Key Points to Plot Skyline

- Measure altitude angles:

A transit would do nicely but is unnecessary. A simple inclinometer can be made from a protractor and a plumb bob. Attach the protractor to the plumb line so it will be comfortably at eye level when the plumb bob is suspended. If you don't have a plumb bob, any weighted object will do; a rusty carriage bolt would work fine.

It is important that the line pass through the correct location on the protractor -- the point where all angles converge. You need only plumb the line once: you can then take a piece of wood with about a 1/2" hole in it and place it so that the hole is at the plumb point. This will keep the bob from swinging and allow you to make many measurements quickly. It will also save you on a windy day. Site each object and record the number of degrees the protractor rotates away from level.

Figure 12. Using An Inclinometer



• Measure azimuth angles:

You've already found true south. Place the rosette on the level working surface, align it properly, and site the azimuth angles. (The rosette in appendix #2 is provided for your use.)

• Measure potential future obstructions:

Small trees might later grow quite large. If they are located on a southerly neighbor's lot and you have no legal protection through local solar access ordinances or an easement, they may someday shade your collector. By identifying the type of tree you can determine its mature height and thereby estimate future shading. By knowing the height of the tree and its distance from the collector you can determine the solar altitude by referring to the Height Angle Distance Table in Appendix #3. After determining azimuth as described, you can plot the potential obstruction on the sunpath chart.

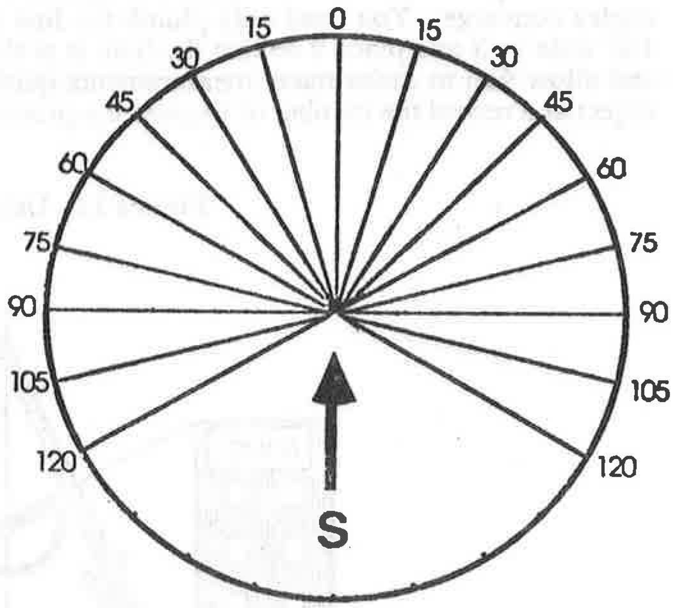


Figure 13. A Rosette

There is also the possibility someone could construct a building that would shade your collector. You can determine the distance to the legal buildable area of the property in question. You can also determine from the local planning department if zoning laws have set height limits for any structures on that property. Once you know the distance and the height, you can look up the altitude angle in the table and plot the potential obstruction on the sun chart.

Now that we have determined the altitude and azimuth for all possible obstructions to our potential solar site, we can simply plot them on the sun chart, and we're ready to assess the results.

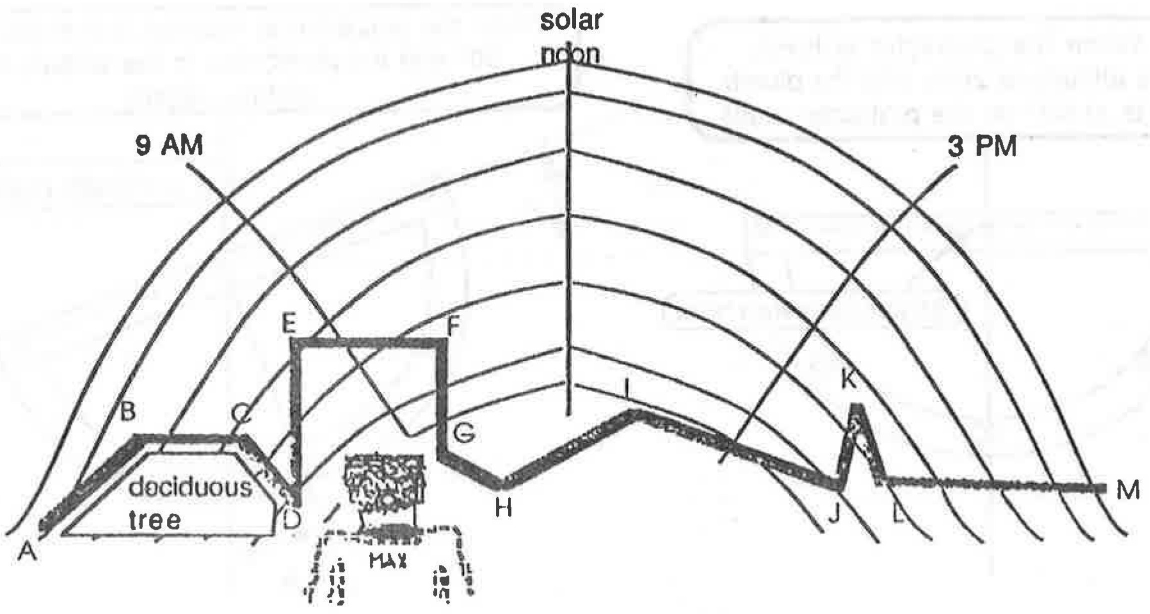


Figure 14. Record Deciduous Tree Locations

CALCULATING THE PERCENTAGE OF SOLAR AVAILABILITY

- Allowing for deciduous trees:

When deciduous trees lose their leaves in winter the amount of insolation blocked is greatly reduced but not eliminated. Different tree species will block a different percentage of sunlight depending on the density of bare branches (see Appendix #4). From 40 to 60 percent blockage is common but the range is much wider. Also, different tree species will lose (and regrow) their leaves at different times of the year. You can obtain assistance identifying and characterizing different species from your agricultural extension agent. Once you know when the leaves will be absent you should mark those unshaded periods on the sun chart:

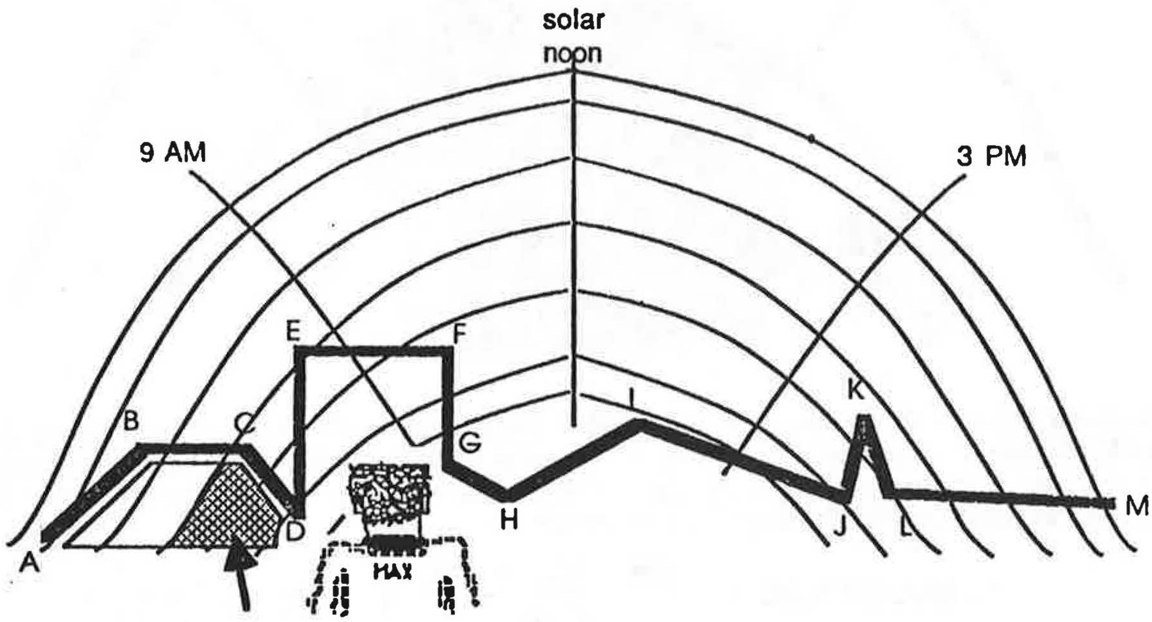


Figure 15. Determine Period When Deciduous Tree Leaves Are Fallen

Only this portion of the deciduous tree blockage is given special allowance in the calculations below. The rest of the deciduous tree area will provide full blockage of sunlight.

- Figuring proportional areas:

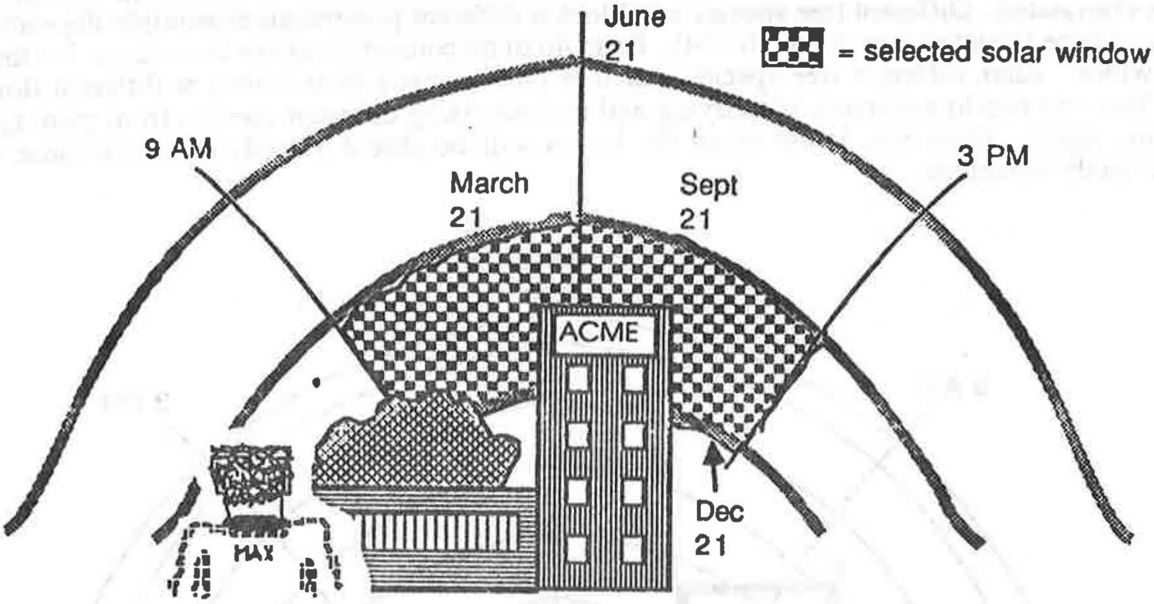
The basic idea is to divide the sun path chart into a grid of equally sized areas in order to make it easy to figure area percentages. The sun path chart in Appendix 1 is an example. We then select any area we wish to consider and count the total number of square(T). We then count the number of squares in our selected area that will be partially shaded by deciduous trees with fallen leaves(D). We finally count the number of squares in the selected area that are fully shaded(S). The percent of blockage is then represented by the formula:

$$\% \text{ BLOCKAGE} = \frac{C\,(D) + S}{T} \times 100$$

where (c) represents the fraction of light blocked by the deciduous trees.

As an example suppose we select the area of the sun chart in the drawing below that represents the sun paths between the hours of 9 AM and 3 PM for the period of September 21 to March 21.

Figure 16. The Number of Blocked Squares is a Percentage of the Total Number of Squares in the Solar Window



We determine that the deciduous tree is a White Birch, that it will have no leaves during this period, and that it will block 54 percent (from table in Appendix 4) of the sunlight. We count 516 total squares in the selected solar window. Then, if the building blocks 80 squares and the birch tree blocks 20 squares, we can calculate the blockage for that period:

$$\% \text{ BLOCKAGE} = \frac{.54\ (20) + 80}{516} \times 100 = 17.6\%$$

Using this procedure we can evaluate the blockage for a variety of different periods. For example, if we know the average solar radiation on a vertical south facing surface for a given month, we can calculate the percent of blockage for that month and obtain an estimate of the available amount of solar energy.

- **Estimating blockage for space heating:**

Generally, the solar window for space heating occurs between the hours of 9 AM and 3 PM from August to April or perhaps September to March. Unless a collector must face strongly east or west these are the important hours. It is more accurate to divide this window into smaller sections to minimize the distortion caused by unfolding a sphere onto a flat plane. Note the additional sunpath (Nov 1-Feb 1) on the chart in Appendix 1 that we'll use to divide this solar window into two halves:

Section A	November 1 to February 1	148 total squares	30 percent of the window's solar energy
Section B	February 1 to April 21	672 total squares	70 percent of the window's solar energy

This division requires a slight addition to the calculation: the percent of blockage calculated for A applies to 30 percent of the total solar energy while the percent of blockage calculated for B applies to 70 percent. So the TOTAL BLOCKAGE for the entire solar window equals:

$$.3\begin{bmatrix}\text{\% BLOCKAGE}\\ \text{Section A}\end{bmatrix} + .7\begin{bmatrix}\text{\% BLOCKAGE}\\ \text{Section B}\end{bmatrix}$$

where the percent of blockage for each section is calculated according to the procedure described above.

- Blockage for water heating:

The procedure for water heating is the same as the above procedure for space heating except for the fact that the selected solar window is different because solar collection takes place all year. For most applications the hours between 9 AM and 3 PM are the important ones. Again, we'll divide this window into two smaller sections:

Section A	Sept. 21 to March 21	516 total squares	40 percent of the window's solar energy
Section B	March 21 to September 21	624 total squares	60 percent of the window's solar energy

Note that we are now using the sun path for March 21 as the boundary between the two sections, and that the percentages have changed so the formula is different too. The TOTAL BLOCKAGE for this solar window equals:

$$.4\begin{bmatrix}\text{\% BLOCKAGE}\\ \text{Section A}\end{bmatrix} + .6\begin{bmatrix}\text{\% BLOCKAGE}\\ \text{Section B}\end{bmatrix}$$

- Drawing Conclusions:

Once these figures are calculated we can estimate the site's solar availability. Remember, this is a general guide:

Total Blockage	*Conclusion*
0-20%	A good solar site
20-40%	Probably a good site
40%+	Probably not

Calculating the percent of shading by using equal sized areas is somewhat inaccurate due to the fact that it does not account for the distortion inherent in folding a three dimensional sphere onto a two dimensional plane (like a Mercator Projection map of the earth). Calculating for smaller time periods increases accuracy.

Also, solar intensity varies. The amount of solar energy delivered to a south facing vertical surface at noon in February is about 20 percent greater than the amount delivered at 3 PM. Also the amount delivered at noon in December is somewhat less than that delivered at noon in February. It is important to realize that the blockage calculation is not an exact indicator of the actual amount of solar energy available to the site. It is an approximation, perhaps accurate to within 7 or 8 percent. Realizing this we can make some qualitative interpretations of the results of our site survey. For example, 20 percent shading in the morning and afternoon hours would be less an energy penalty than 20 percent shading at noon. For a more detailed calculation of solar intensity refer to *The Passive Solar Energy Book* which is listed under "Suggested Reading."

The purpose of the solar site is important too. A passive solar home could tolerate significant shading in December and still perform well, whereas a solar greenhouse meant for a year-round food production would be severely handicapped. On the other hand a year-round solar water heating application might still be appropriate with full shading from November until February.

Written by Mike Nuess.

SUGGESTED READING

The Passive Solar Energy Book, Edward Mazria, Rodale Press. 1979
Can walk you through the survey process as well as provide a lot of other theory. The rules of thumb are more useful for a sunny climate.

A Solar Greenhouse Guide to the Pacific Northwest, Ecotope Group, and A Solar Water Heater Workshop Manual, 1979.
Either of these has plenty of information to explain the survey as well as other relevant information.

The Solar Home Book, Bruce Anderson, Chesire Books, 1976.
Good.

Solar Retrofit, Daniel K. Reif, Buck House, 1981.
Good basics plus description of how to build a shading mask.

Solarizing Your Present Home, Joe Carter, Rodale Press, 1981.
Good chapter on plotting as well as calculations for determining shadow heights.

Washington State Solar Manual, Washington Association of Building Officials, 1983.
Discussion of fundamentals and plotting the skyline as well as other topics.

Site Planning for Solar Access, and Protecting Solar Access for Residential Development, Duncan Erley and Martin Jaffee, The American Planning Association for WSHUD.

Solar Access Ordinances in the Northwest, Washington State Energy Office, 1982.

Washington Energy Extension Service, a Seattle University and Washington State Energy Office program, is funded by the Bonneville Power Administration and the U.S. Department of Energy.

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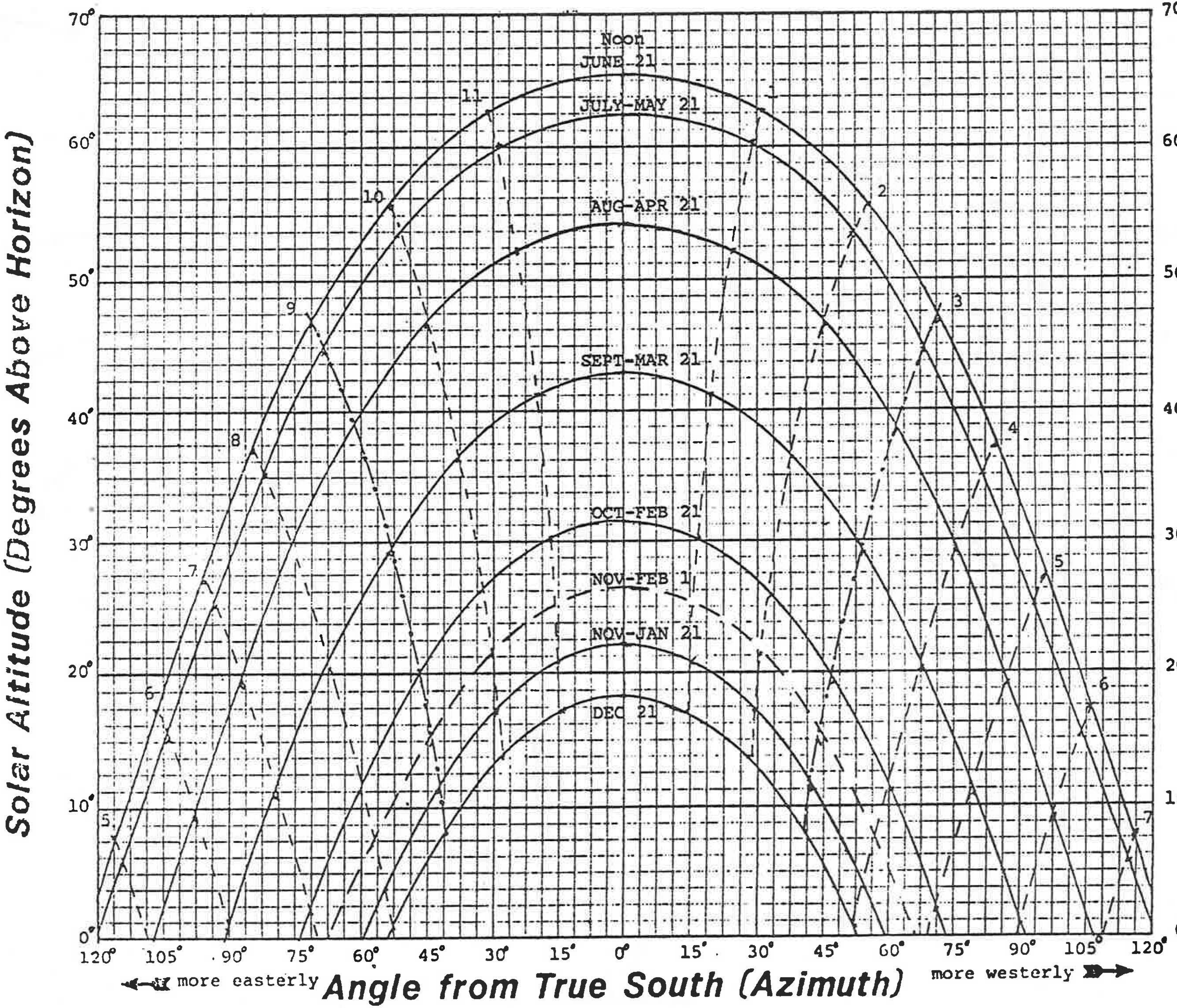
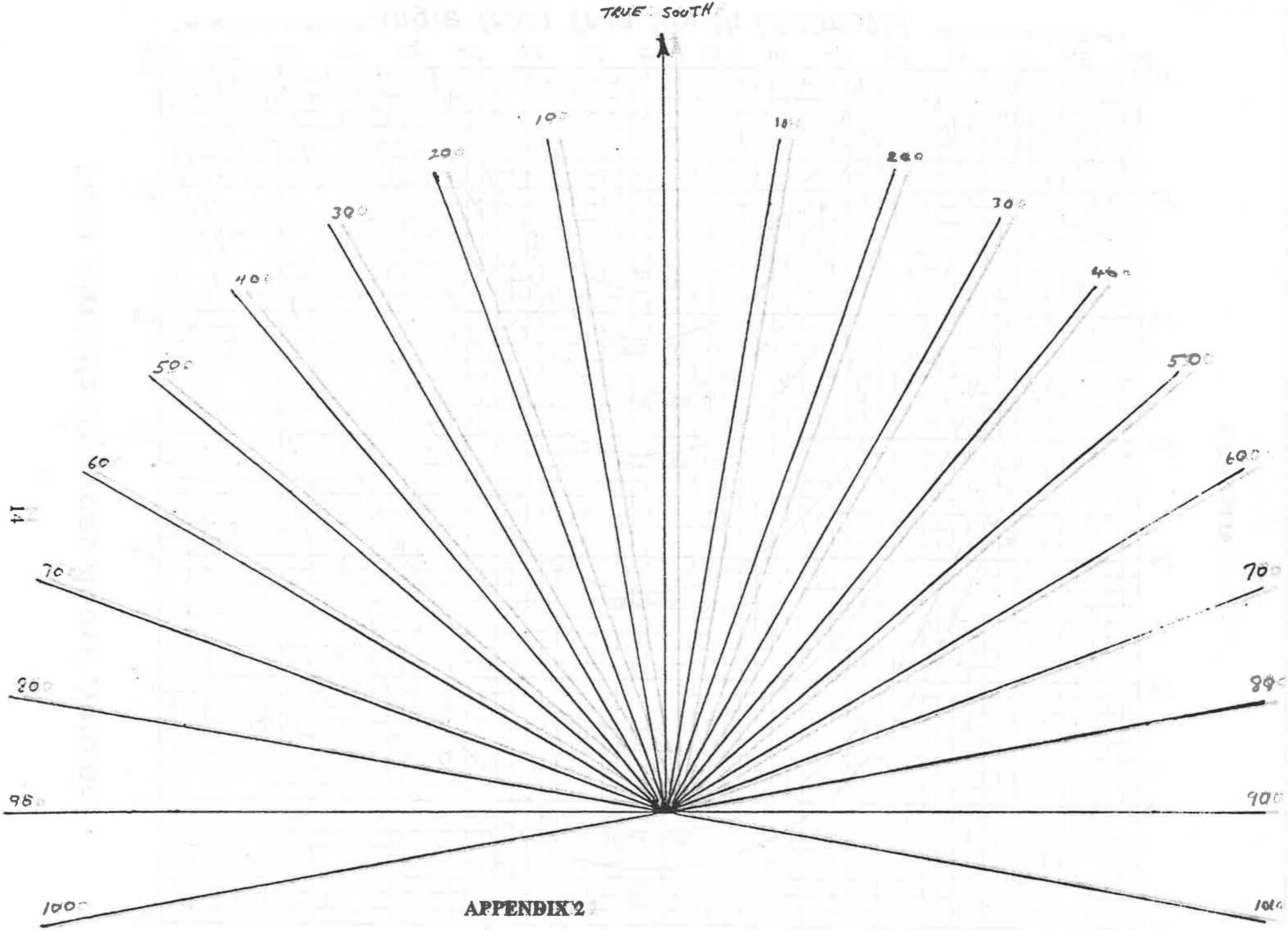
Sun Path Chart (48°N)





APPENDIX 2

ROSETTE

APPENDIX 3

HEIGHT, ANGLE, AND DISTANCE TABLE

Angle in Degrees

	H	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°
	1	11	5	3	2	2	1	1	1	1				
	2	22	11	7	5	4	3	2	2	2	1	1	1	
	3	34	17	11	8	6	5	4	3	3	2	2	1	1
	4	45	22	14	11	8	6	5	4	4	3	2	2	1
	5	57	28	18	13	10	8	7	5	5	4	3	2	2
	6	68	34	22	16	12	10	8	7	6	5	4	3	2
	7	80	39	26	19	15	12	10	8	7	5	4	4	3
	8	91	45	29	22	17	13	11	9	8	6	5	4	3
	9	103	51	33	24	19	15	12	10	9	7	6	5	4
	10	114	56	37	27	21	17	14	11	10	8	7	5	4
	15	171	85	56	41	32	26	21	17	15	12	10	8	6
	20	229	113	74	54	42	34	28	23	20	16	14	11	9
	25	286	142	93	68	53	43	35	29	25	21	17	14	11
	30	343	170	112	82	64	52	42	35	30	25	21	17	14
	35	400	198	131	96	75	60	50	41	35	29	24	20	16
	40	457	227	149	110	85	69	57	47	40	33	28	23	18
	45	514	255	168	124	96	77	64	53	45	37	31	26	21
Height	50	572	284	187	137	107	86	71	59	50	42	35	28	23
	55	629	312	205	151	118	95	78	65	55	46	38	31	25
	60	686	340	224	165	129	104	85	71	60	50	42	34	28
	65	743	369	243	179	139	113	92	77	65	54	45	37	30
	70	800	397	261	192	150	121	100	83	70	58	49	40	32
	75	857	425	280	206	161	130	107	89	75	62	52	43	35
	80	914	454	299	220	172	139	114	95	80	67	56	46	37
	85	972	482	317	234	182	147	121	101	85	71	59	49	39
	90	1029	510	336	247	193	156	129	107	90	75	63	52	42
	95	1086	539	355	261	204	165	136	113	95	79	66	54	44
	100	1143	567	373	275	214	173	143	119	100	83	70	57	46
	105	1200	595	392	288	225	182	150	125	105	88	73	60	49
	110	1257	624	411	302	236	191	157	131	110	92	77	63	51
	115	1314	652	429	316	247	199	164	137	115	96	80	66	53
	120	1372	681	448	330	257	208	171	143	120	101	84	69	56
	125	1429	709	467	343	268	217	179	149	125	105	87	72	58
	130	1486	737	485	357	279	225	186	155	130	109	91	75	60
	135	1543	766	504	371	290	234	193	161	135	113	94	77	63
	140	1600	794	522	385	300	242	200	167	140	117	98	80	65
	145	1657	822	541	398	311	251	207	173	145	122	102	83	67
	150	1715	851	560	412	322	260	214	179	150	126	105	86	69

APPENDIX 4

LIGHT PENETRATION OF VARIOUS TREES

Common Name	Evergreen Deciduous	Tree Height	Tree Width	% light transmitted summer	% light transmitted winter	% blockage winter
Big Leaf Maple	D	30-90'	30-60'	15	40	60
Norway Maple	D	25-60'	20-50'	11	61	39
Red Horse Chestnut	D	30-40'	25-30'	8	53	47
White Alder	D	40-80'	20-40'	11	35	65
European White Birch	D	40-60'	20-30'	11	46	54
Silver Dollar Gum	E	30-70'	10-40'	20	20	80
California Sycamore	D	40'	50'	5	42	58
Thornless Honey Locust	D	50-75'	50-75'	30	46	54
Red Gum	E	80'	40'	11	11	89
Moraine Ash	D	40'	20'	13	-	-
Western Cottonwood	D	60'	40'	26	38	62
American Sweet Gum	D	60'	20-25'	13	68	32
Ponserosa Pine	E	50-150'	15-25'	19	19	81
Pin Oak	D	50-80'	35-40'	11	-	-
Silver Maple	D	60-100'	50-100'	14	63	37