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WORKING TOWARD AN AUTONOMOUS
LIVING ENVIRONMENT

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WORKING TOWARD AN AUTONOMOUS
LIVING ENVIRONMENT

by

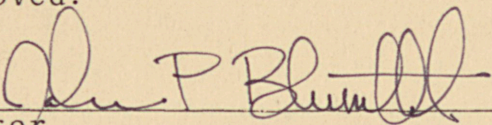
Jeffery Lynn Kelley

A thesis submitted in partial fulfillment
of the requirements for the degree

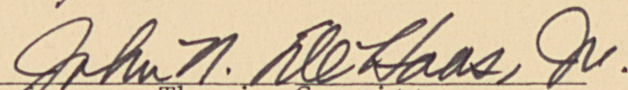
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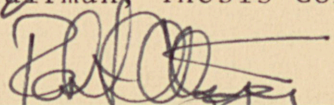
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MONTANA STATE UNIVERSITY
Bozeman, Montana

December, 1979

To my parents for their love, help and understanding.

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INTRODUCTION

In today's world of high technology, rapidly inflating prices, and decreasing world resources man faces many financial and psychological problems. The all electric house of today is a very convenient and comfortable habitat in which to live, but what if the electricity was cut off? The occupants would find themselves in a relatively hostile environment, with no heat in winter; no light, refrigerator, cooked meals, microwave ovens, electric knives, television, and no electric garage door openers (which they would not need anyway because the car is downtown in line for gas). Surely even a temporary loss of "everything" would cause tension and anxiety in even the wealthiest of families. What about the not so wealthy: the guy who watches his spending carefully just to feed his family? His worries start with next month's meals.

Present trends in electricity and food production and distribution only escalate the economic problems many Americans face today. For example, today's method of electrical production on a regional or interstate scale is an extremely inefficient use of fossil fuels, with great losses in productions as well as in transportation to locally

specific uses. With decreasing fuel supplies and increasing demands future blackouts can be expected. Another major economic problem we face is food. With an increased United States and World population there can be an expected rising demand on U.S. foods. America now enjoys an abundant supply of a wide variety of food stuff, but with increases in the cost of production, transportation and marketing, brought about by higher petroleum prices, the consumer prices are growing steadily higher. Combine this with a rising demand and we can expect prices to skyrocket. There seems to be no ceiling and many Americans can only expect the worst: higher prices and possible shortages in the future for their basic needs.

In the past, many of our forefathers enjoyed the benefits of locally specific sources of power and food production. The early homesteader "lived off the land". He worked hard but benefited because his dependence upon urban society was minimal. His life was simple but he enjoyed an economic market he readily understood. Although I cannot see a complete return to a self-sufficient world of the past, I see an ever increasing need to create an environment for those who want to return to a gratifying sense of self-reliance; a persons ability to support himself

regardless of ever increasing inflation and the unsure
future of rapidly depleting fossil fuels

Through the use of present ecological knowledge
and technical technology a psychologically viable, self-
supporting living environment can be obtained.

THEESIS STATEMENT

Through the use of present ecological knowledge and mechanical technology a psychologically viable, self-supporting living environment can be obtained.

Explanation of Procedure

In my introduction I looked briefly at a need to move toward self-reliance. My thesis statement sums up this thought and touches on the areas I wish to address in my thesis. Ecological knowledge and mechanical technology pertain to the user's metabolic processes, the mechanical and non-mechanical systems utilized, and the site of the project. Psychological viability deals with the occupant or user; his participation in the system, demands on his lifestyle, and possible benefits from this interaction. A design for a self-supporting living environment will be the ultimate outcome of the project. Before I get into these aspects of my thesis I feel a brief discussion of architecture with regard to energy use will be useful to further clarify a need for this project.

Architecture and Energy

A background to further inform the reader
of a need for this project

An article by Richard G. Stein called Architecture and Energy,¹ is one of the best I have read which deals with the problems current architectural practices have in dealing with the energy picture. He says that the built environment is responsible for about a third of all energy use in the United States. In the article he identifies many aspects of the built environment which are wasteful of our energy resources and says that the decisions made by architects and engineers can reduce energy expenditures in our buildings by at least 50 percent.

Stein expresses the real seriousness of the energy situation we face with predictions of the dates when we will run out of our resources at current projected rates of use. He also spells out several other effects of energy use, such as environmental damage and pollution. By comparing the United States to the rest of the world, in terms of energy consumption, he shows how extravagant our society really is.

On the architectural side of the picture he looks in

some detail at the various energy consumers within the building, explaining why they are wasteful of primary energy, and what can be done to limit this waste. Identifying the tall, glass-faced, sealed commercial building as a significant energy user, he gives it close analysis, pointing out that decade by decade, energy use per square foot has been increasing although the performance of the building, the services rendered for the tenants, has been largely unchanged. Stein takes a close look at structure, lighting, electric heating, ventilation, and the various other mechanical systems, pointing out what could and should be done to eliminate energy waste.

Stein points out that the architect is not totally at fault. He says big business and clients of architects and other designers of our built environment are reluctant to accept the present slight increase in initial cost of a building with energy conservation principles involved. This first cost mentality fails to take into account the life-cycle cost, not only the design and construction costs but also the cost of operating and maintaining the building throughout its life. These people always refer to so many dollars per square foot and never the cost of energy per square foot. By reducing operating costs for

energy per square foot an additional sum per square foot could be spent on construction. Even though the escalation of operating costs increase from year to year, the payment of construction costs remains constant from the year of financing. Even where the economics of an energy conscious building can be shown to be favorable, there is a tendency to think only of the first cost.

Because we have built our culture and standard of living on easy energy that is becoming more expensive, we must look for answers to the problems of dealing with conservation and developing alternative energy sources which are capable of feeding our excessive needs. The decisions made by architects greatly affect the energy use problem. Conservation seems to be the best solution to the problems we face today. The only practical energy resources that can provide steel for windmills, plastic or glass for solar collectors, greenhouses, etc., are the fossil fuels such as coal, oil, and natural gas. If we can cut the energy expenditures of our buildings, our fossil fuel resources will last much longer, buying time for a future society based on renewable energy.

FOOTNOTES

1. Stein, Richard G.; "Architecture and Energy,"
Forum, July/August, 1973, pp. 38-58.

SYSTEMS ANALYSIS

Systems Analysis

Today there are a great number of mechanical systems to provide a building with heat, light, water and other functions which make it livable and comfortable for the occupant. As explained previously, many of these systems commonly used are very inefficient and wasteful. There is a large influx of so-called energy conscious concepts and products which are not yet proven to be viable by objective tests or standards. Furthermore, there isn't sufficient experience to rate the various alternative systems and compare their efficiency, cost, and savings over conventional systems. Through my research I have been exposed to a wide variety of concepts and systems. Many researchers have incorporated alternative systems in buildings and have provided examples of the systems potential. I have included in this brief analysis only systems which work and are cost effective now or will be in the very near future.

Solar Energy Systems

For centuries man has made use of the sun's energy. Most of our food and fuel have been made possible by the sun through photosynthetic combinations of water and atmospheric carbon dioxide in growing plants.

"Fossil fuels represent energy photosynthesized and stored in dead plant and animal matter millions of years ago. The earth's climate is also dependent on solar energy. The winds, rivers and ocean currents all rely on the daily heat from the sun for their motion. Man has long made use of these forms of solar energy. He has used the wind and water currents to move from place to place; and he has used the sun to grow his food and warm his shelter".¹

The heat available from the sun can be absorbed directly in a building to heat its spaces and water. There are several different approaches, both active and passive. Active collection is a term used to classify those systems which use mechanical devices to keep the system in operation, such as a fan or pump to keep the heat transfer medium circulating. Passive collection deals with those systems which do not use mechanical devices to

keep the system in operation. Air flow can be handled passively by utilizing the principle that hot air rises. By allowing the cool air in at the bottom and heated air out the top of a heating device, the principle of convection could be used to eliminate the need for a mechanical device to circulate the transfer medium.

Solar collectors are devices which trap usable solar radiation. There are numerous concepts for the collection of solar radiation. These concepts range from the most simple -- a window, an example of passive collection -- to those that are quite complex -- a solar cell, an example of active collection which must be cooled to work efficiently. Solar collectors can be classified as either focusing or non-focusing. A non-focusing collector is one in which the absorber area is equal to the aperture for incident radiation. A focusing collector, however, is one in which the absorber area is smaller than the aperture for incident radiation and there is a concentration of energy onto the absorber surface.

Passive solar gain can begin with proper window placement. Glass permits the inward passage of solar radiation, but doesn't allow long-wave, outbound radiation

to escape. This is known as the "greenhouse effect".

"The energy we receive from the sun is in the form of "high quality" radiation of short-wave length (some of which is visible to the eye)".² "Glass, probably the best glazing material, transmits about 90% of the incident radiation. Of the remaining 10%, half is reflected and half absorbed by the glass itself".³ Like a large south facing window, a greenhouse attached to the structure can provide usable heat to adjacent spaces and provide it passively. A massive north wall on a south facing greenhouse will act as a storage device and help heat a greenhouse by reradiating its stored heat as the greenhouse temperature drops at night.

A flat-plate collector also uses the greenhouse effect and has the ability to use diffused sunlight as well as direct radiation, but unlike a simple window, it allows collected radiation to be transferred to another location for storage. A flat-plate collector contains five basic parts.⁴

1. Transparent cover plate (glazing) which may be one or more sheets of glass or plastic.
2. Absorber plate, generally a highly conductive material such as copper or aluminum, coated with a blackened or selective surface.
3. Tubes or fins that circulate heat transfer fluid

to carry heat away from the collector's surface. They can be either fastened to the plate or integral to the collection surface.

4. Insulation which prevents downward heat loss from the collector plate.
5. A container which protects the entire assembly from the environment and from heat loss due to conduction. This may be integral to the structure of the building.

The overall operation of a flat-plate collector is relatively simple. The sun's radiation is transmitted through the transparent cover plate or glazing material and is picked up in the form of heat by the highly conductive absorber plate. As the temperature of the absorber plate rises the heat it re-radiates is trapped due to the greenhouse effect of the cover plate or glazing. The fins or tubes within the absorber plate contain the heat transfer fluid which carries heat away from the collector's surface. The transfer fluid can be air or a liquid such as water. The warmed fluid may be used immediately for heating purposes or heat may be extracted from it for storage.

Focusing collectors can produce much higher temperatures than flat-plate collectors. Utilizing optics, a focusing collector directs all incident sunlight to a point (the focal point) or line (the focal axis) through

which an enclosed circulating medium is passed. There are two basic components to any focusing collector.

1. The focusing unit.
2. The pipe containing the circulation medium which actually collects the heat.

The focusing unit consists of a frame covered with a highly reflective material or a lens which refracts the sunlight as it passes through rather than as it is reflected.

The pipe containing the circulating medium is the receiver and should be coated with a paint that can absorb high temperatures. There are two disadvantages to focusers.

The production of high temperatures requires virtually unclouded direct sunlight; if direct sunlight is not available, the focuser collects little usable energy.

Consequently, the use of focusers is now limited to areas with very few days of cloud cover during the heating season. Most focusers require sun-tracking for continued focusing. Continuous tracking requires automatic equipment which can be expensive, but these costs can be outweighed in areas that received a high percentage of direct sunlight when applied to uses which require higher temperatures.

Proper window placement requires virtually no additional costs to a building and can provide a great

deal of the space heating requirements. Flat-plate collectors or a greenhouse attached to a structure do require some additional construction costs but in the long run, when properly designed can provide appreciable savings over conventional fuel fired systems.

Energy Storage System

Since periods without sunshine are inevitable, it may be necessary to include a storage system for a solar-heated building. Short term storage is needed at night when the collectors are inoperative. A long term storage is needed when there are several days without adequate sunshine due to storms or cloud cover. A properly designed storage system with some auxiliary heating will keep the building comfortable through these periods. The sizing of the storage is a factor of climate, cost and availability and type of auxiliary heating system. A small storage unit has the advantage of better space utilization and lower cost. There are several techniques of energy storage. The simplest is the sensible heat storage method. This is where energy is stored in a suitable substance by increasing its temperature. To increase the storage capacity, the volume of the substance is increased or the temperature is further increased. Increasing the capacity by increasing the volume is limited by cost of the material, the container to hold it and the amount of energy available as an input. The space provided for storage will also be increased.

If the temperature is increased, the prevention of unwanted heat loss becomes a problem. The two common materials for sensible heat storage are water and rocks.

Water Supply Systems

Water quality requirements vary considerably depending upon the expected use. If the water is for domestic use, it must be free of water-borne diseases, toxic materials, or noxious mineral and organic matter. For the irrigation of crops, water quality requirements are much lower and easily met. The best way to determine the quality of a given source of water is to consult a competent authority and then make a decision on the necessary treatment needed, if any. There is no fool-proof way to establish a minimum quantity of water needed per capita. Consumption varies for different locations, climates and conditions (a person will use less water if he has to hand pump it). There are tables to establish the basic size requirements for the water supply and distribution system. After a preliminary assessment of the amount of water needed, it must be determined if there is enough water available to meet this need. Several sources of water may be available for use. Ground water may be collected through the use of wells, infiltration galleries and springs. Surface water is commonly taken from a small stream, river or lake. The collection of rain water is yet

another possibility.

Bio Fuels

"Bio fuels are as the name implies, renewable energy sources from living things. They are to be distinguished from fossil fuels which are also of biological origin, but which are not renewable. All bio fuels are ultimately derived from plants, which capture the sun's energy, convert it to chemical energy by photosynthesis, and in the process of being eaten or decayed, pass this energy on to the rest of the living world. In this sense, then, all forms of life, their byproducts and wastes, are storehouses of solar energy ready to be eaten, burned or converted into various organic fuels."⁵

Bio fuels offer a great advantage over fossil fuels because they are renewable and virtually unexhaustable. With proper management these sources of energy could last forever and help limit use of the fossil fuels, which due to this limited existence will one day run out. Three areas of this topic are Aquaculture, Methane Systems and Wood.

Webster defines aquaculture as the growing of sea animals or plants for human consumption or use. It is

a low energy, low cost, and ecologically sound endeavor. "There are definite advantages to culturing fish as a food source. For one thing fish are able to produce more protein per pound of food eaten than, a cow, chicken or any other land animal. There are two basic reasons for this. Fish and shellfish live in a medium that has about the same density as their bodies and as a result they don't have to spend much energy supporting themselves against gravity. Thus, aquatic animals to have a reduced skeleton and a greater ratio of flesh to bones; a definite advantage for a food species. Fish and shellfish are cold-blooded, and their body temperatures are essentially that of their surroundings. Because of this they don't have to spend much energy maintaining warm body temperatures as do warm blooded birds and mammals. There are other advantages. Fish live in a three dimensional world where nutrients necessary for growth are distributed throughout a volume. So for a given area aquaculture can yield more food than land based animal husbandry."⁶ An aquaculture system can also incorporate hydroponics to produce vegetables. When an aquaculture system is utilized to its full potential it could greatly reduce the amount of consumable food which must be purchased. Often, bought

consumables must be produced and shipped from very distant locations consuming fossil fuels in the entire process. As an example of the possibilities with aquaculture, one such system by D. Mendola of the New Alchemy Institute⁷ can produce 1,000 pounds of edible meat, and an unknown quantity of clams and vegetables for \$1,000 a year mortized over 10 years. The meat yield would be 900 pounds of freshwater prawns which provide 450 pounds of meat and 400-600 pounds of fish meat.

"Methane digestion has been used by sanitary engineers in the treatment of domestic sewage sludge and organic wastes for decades, but as a process found in nature, it is older than man."⁸ Methane digesters are not only a way to process organic wastes but also provide other benefits. By looking at the stratification in a methane digester you can analyze the uses of its products.⁹ The upper layer or lightest layer is the combustible bio gas which is 2/3 methane gas (CH_4). It is a result of bacteria breaking down the organic waste and producing large bubbles. Methane gas can be used as a substitute for natural gas in most applications such as cooking or heating. More important is the supernatant which provides the algae pond of an aquaculture system with nutrients.

The digested sludge is heavier and collects near the bottom of the digester and can supply fertilizer for compost and soil conditioning for a greenhouse or garden. There are several types of continuous feeding digesters which are either vertical or horizontal in configuration.¹⁰

"After serving as the main home heating fuel for centuries, wood was largely abandoned when coal, oil, and gas became available."¹¹ Fireplaces have continued to be a decorative feature in homes, but their role in heating has largely been neglected. However, as a supplement to alternative heating methods, properly managed wood fires can provide sufficient backup. Many conventional fireplaces draw more warm air out of a house than they put into it. Wood can be utilized more efficiently if a complete combustion burner is used. "An automatic airtight stove is the most efficient wood heater available."¹² According to the Portola Institute, it has an air intake damper controlled by an automatic thermostat, if the stove overheats, the damper closes automatically, and more air is allowed in if the fire gets too low. A secondary intake system, which circulates unburned gases back through the fire helps increase efficiency. It can maintain a fire for 12-24

hours. An automatic airtight stove can also incorporate coils for hot water heating, another advantage as a solar backup system. Designed for maximum efficiency, the flames are hidden from view. This can be a disadvantage because many people feel an inner comfort or even entertainment while watching a fire burn.

This presents considerable problems, with the main concern being utilizing wind energy in such a way as to be predictable and it is not as constant as the sun. Unlike windmills which use wind directly for mechanical energy, a wind driven generator converts wind energy into electrical energy. A complete wind driven generator installation consists of:

1. A tower to support the wind generator.
2. Devices regulating generator voltage.
3. The propeller and generator system.
4. The tail vane.
5. A storage system to store power for use during windless days.
6. An inverter which converts the stored direct current (D.C.) into regulated alternating current (A.C.).

A wind generating system can be home built and reasonably cheap, but a commercial system is more reliable, will last

Wind Driven Generators

Wind is another form of energy created by the sun. It is the reaction of the atmosphere to unequal distribution of incoming energy from the sun. Heat causes low pressure areas and lack of heat results in high pressure areas. This pressure imbalance generates wind. The main concern when utilizing wind energy is that it is not predictable and it is not as constant as the sun. Unlike windmills which use wind directly for mechanical energy, a wind driven generator converts wind energy into electrical energy. A complete wind driven generator installation consists of:¹³

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3. The propeller and generator system.
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6. An inverter which converts the stored direct current (D.C.) into regulated alternating current (A.C.).

A wind generating system can be home-built and reasonably cheap, but a commercial system is more reliable, will last

longer and will provide a greater amount of electricity.

In most areas of the world, mechanical refrigeration is achieved by the use of refrigerants which are designed to absorb heat from the space being cooled. This is done by the use of a cycle which involves the compression and expansion of the refrigerant. The compression of the refrigerant raises its temperature and the expansion lowers it. The heat is then removed from the space being cooled by the expansion of the refrigerant. This process is repeated continuously to maintain the desired temperature. The efficiency of this process is determined by the type of refrigerant used and the design of the system. The most common refrigerants are Freon, R-12, and R-22. These are all hydrochlorofluorocarbons (HCFCs) and are known to be harmful to the environment. Therefore, the use of these refrigerants is being phased out in many countries. The replacement of these refrigerants with more environmentally friendly alternatives is a major goal of the international community. The design of the refrigeration system is also crucial to its efficiency. The use of variable speed compressors and other energy-saving devices can significantly reduce the energy consumption of a refrigeration system. The design of the condenser and evaporator coils is also important. The use of micro-fins and other advanced coil designs can improve the heat transfer efficiency of the coils. The design of the entire system, including the piping and controls, is also critical to its performance. The use of computer-aided design (CAD) and other advanced design tools can help engineers optimize the design of a refrigeration system for maximum efficiency and minimum environmental impact.

A basic principle of refrigeration is the transfer of heat from a space being cooled to a space being heated. This is done by the use of a cycle which involves the compression and expansion of the refrigerant. The compression of the refrigerant raises its temperature and the expansion lowers it. The heat is then removed from the space being cooled by the expansion of the refrigerant. This process is repeated continuously to maintain the desired temperature. The efficiency of this process is determined by the type of refrigerant used and the design of the system. The most common refrigerants are Freon, R-12, and R-22. These are all hydrochlorofluorocarbons (HCFCs) and are known to be harmful to the environment. Therefore, the use of these refrigerants is being phased out in many countries. The replacement of these refrigerants with more environmentally friendly alternatives is a major goal of the international community. The design of the refrigeration system is also crucial to its efficiency. The use of variable speed compressors and other energy-saving devices can significantly reduce the energy consumption of a refrigeration system. The design of the condenser and evaporator coils is also important. The use of micro-fins and other advanced coil designs can improve the heat transfer efficiency of the coils. The design of the entire system, including the piping and controls, is also critical to its performance. The use of computer-aided design (CAD) and other advanced design tools can help engineers optimize the design of a refrigeration system for maximum efficiency and minimum environmental impact.

Natural Cooling and Ventilation

In most areas of the world, mechanical refrigeration to achieve physical comfort is compensation for poor designing. With basic knowledge of orientation, site planning and building structure, the designer can avoid a need for highly energy consumptive systems. "Physical comfort during hot months may be shown to be directly related to metabolism and heat removal."¹⁴ Metabolism, discussed in more detail under "User Needs", is the production of heat by the human body."¹⁵ The removal of excess heat can be accomplished through natural ventilation.

A basic principle of natural cooling in the temperate zone of the northern hemisphere is to shade all openings facing southwest, south, and southeast against penetration of solar radiation in summer months and to allow its entrance in the winter. This shading can be done by overhangs and other forms of projections around a window, interior and exterior shades and vegetation in the form of deciduous trees and vines. Solar angles should be calculated (see appendix) to find out specific needs in the design.

Due to high heat absorption of roofs, because of their exposure to summer solar radiation, insulation can increase cooling efficiency. Water cooled roofs can greatly reduce the effects of solar radiation. "Placing the insulation above the ceiling and then ventilating the space between the roof and insulation helps, but water ponds tend to reduce the solar radiation penetration before it even gets that far."¹⁶ Water ponds act through reflection and evaporation to reduce the solar impact. "The loss of only 1.37 gallons of pond water can produce the effect of a ton of refrigeration."¹⁷

Natural cooling can greatly reduce the impact of solar heat and when supplemental with the use of natural ventilation, the two can effectively replace the modern air conditioner. Two natural circulation techniques can be used; wind-induced, cross-ventilation and gravity ventilation.

For proper cross-ventilation two openings are necessary. The inlet is located on the windward side of the structure where air pressures are high. An outlet is located on the leeward side where air pressures are low. Because of this pressure difference air is circulated through the structure removing heat and also creating a

cooling sensation due to the air movement itself. Cross-ventilation is most effectively accomplished by using a small inlet located near the bottom or middle of the windward wall and a large outlet in any position on the leeward wall.¹⁸

Gravity ventilation is caused by cool, dense air displacing warm, less dense air. This displacement causes the warm air to rise. Vents are placed at different levels in an interior space. Cool air is drawn in through the lower inlet, forcing the warm air out through the higher outlet. The rate at which air circulates is related to three factors; the difference between the two vents, and the size of the two apertures. Because of temperature difference factors, inlets should be as low as possible where there are likely to be the lowest air temperatures. The north wall of a structure will most likely have the lower air temperatures. Outlets should be located as high as possible. Wind movements can be used to create a suction or "stack" effect which aids in the ventilation process and these desirable actions should be considered in outlet placement. Gravity ventilation can also be used in specific locations, such as bathrooms and kitchens where air exchanges rather

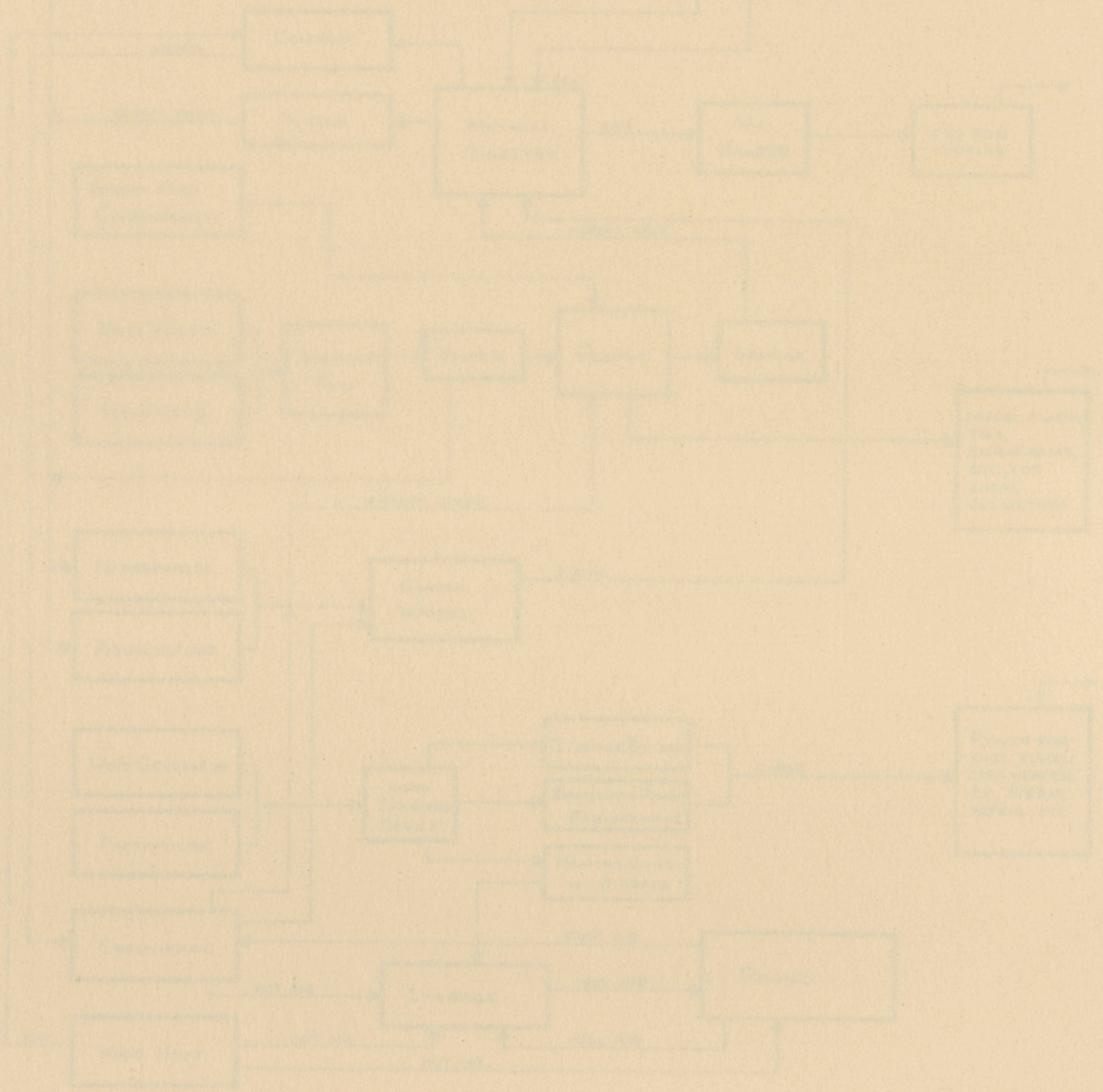
than cooling is required.¹⁹

Integrated Systems

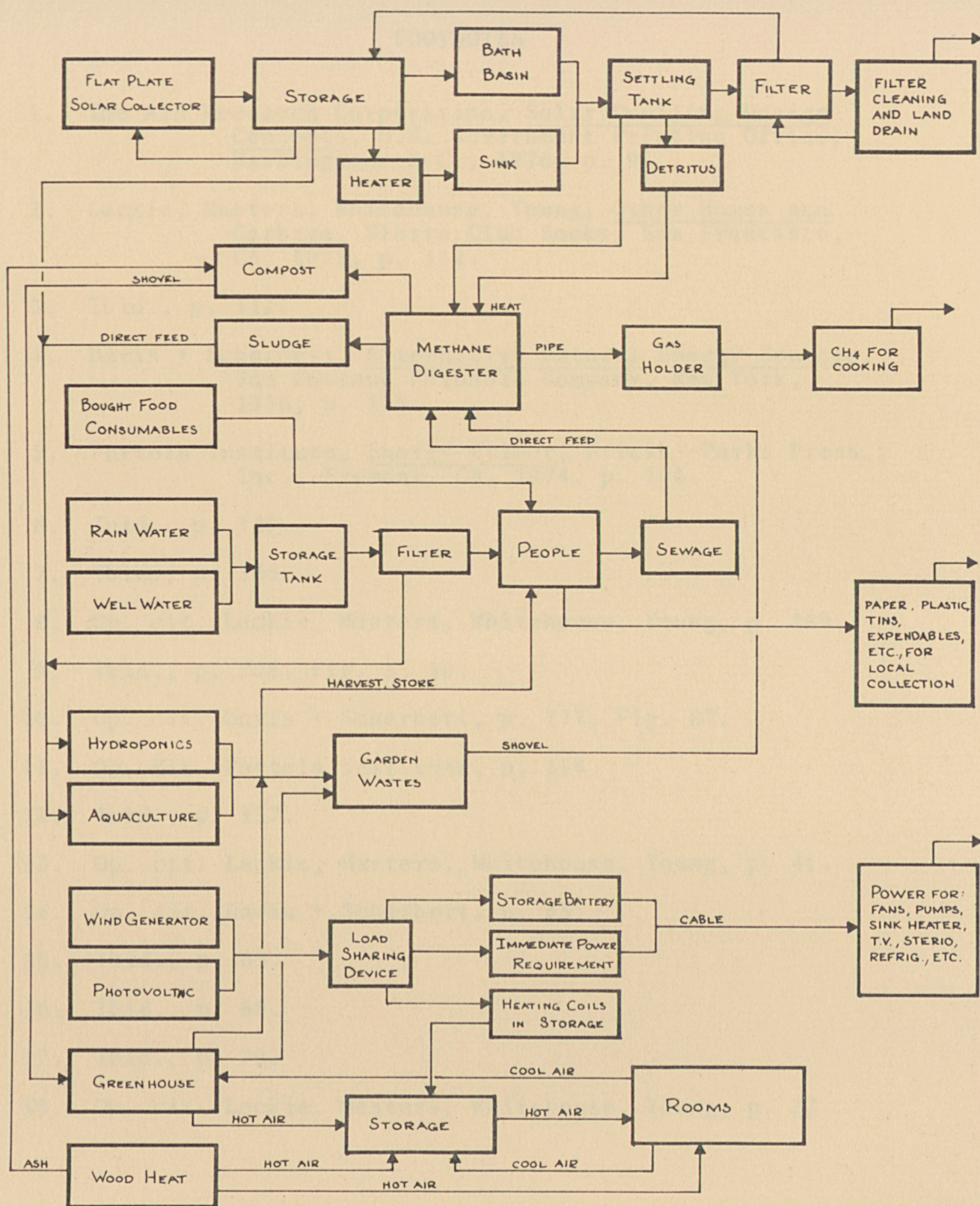
So far separate energy systems have been discussed. . . solar, wind, water, and bio fuels. As pointed out by the Portola Institute, no single source of energy is likely to fill all the power needs for a home, group or community because the supply of each of these natural energy sources is intermittent. At any one time energy demand may exceed energy supply. Each energy source comes in a different form, which makes it suitable for different uses. Solar energy is in the form of heat. Wind energy can provide electricity to run lights and mechanical devices. Bio fuels are forms of chemical energy that are usually more portable and versatile. Integration of these sources, combining and sharing their energy benefits and waste products, can provide reliable and economic power supplies under a variety of conditions.

"Integrated energy systems can be defined as diverse energy sources combined with one another to provide continuous energy."²⁰ Think of them as interdependent. The methane digester produces gas for cooking. It also can provide nutrient rich sludge for the aquaculture which provides food for the occupant. Human waste can

be used to provide fuel for the methane digester. A look at the following flow chart generated in part from a similar example by B. Vale,²¹ will help give some insight into the various interrelationships within an integrated system.



SYSTEM INTEGRATION



FOOTNOTES

1. The AIA Research Corporation, Solar Dwelling Design Concepts, U.S. Government Printing Office, Washington, D.C., 1976, p. 9.
2. Leckie, Masters, Whitehouse, Young, Other Homes and Garbage, Sierra Club Books, San Francisco, CA, 1975, p. 112.
3. Ibid., p. 112.
4. Davis + Scherbert, Alternative Natural Energy Sources, Van Nostand Reinhold Company, New York, 1976, p. 125.
5. Portola Institute, Energy Primer, Fricke--Parks Press, Inc., Fremont, CA, 1974, p. 106.
6. Ibid., p. 129.
7. Ibid., p. 136.
8. Op. cit. Leckie, Masters, Whitehouse, Young, p. 189.
9. Ibid., p. 208, Fig. 5. 10.
10. Op. cit. Davis + Scherbert, p. 177, Fig. 87.
11. Op. Cit. Portola Institute, p. 154.
12. Ibid., p. 157.
13. Op. cit. Leckie, Masters, Whitehouse, Young, p. 41.
14. Op. cit. Davis + Scherbert, p. 65.
15. Ibid., p. 65.
16. Ibid., p. 68.
17. Ibid., p. 70.
18. Op. cit. Leckie, Masters, Whitehouse, Young, p. 22

(paragraph paraphrased from).

19. Ibid., p. 22 (paragraph paraphrased from).
20. Op. cit. Portola Institute, p. 178.
21. Steadman, Philip; Energy, Environment and Building,
Cambridge University Press, Cambridge,
1975, p. 267.

BASIC PROJECT CRITERION

Basic Project Criterion

The project will consist of buildings which are four family structures grouped with consideration for site planning and orientation. They will provide much of the physical needs of the occupants, such as energy, food, working and living space. When designing a building that is working towards self-sufficiency, there are a few basic design characteristics which will give the structure some guidelines from which to generate and help it operate in an overall more efficient manner. A decision to build underground or partly underground, the use of an integrated central core, and consideration of orientation vs. thermal gain should all be considered in a project of this nature.

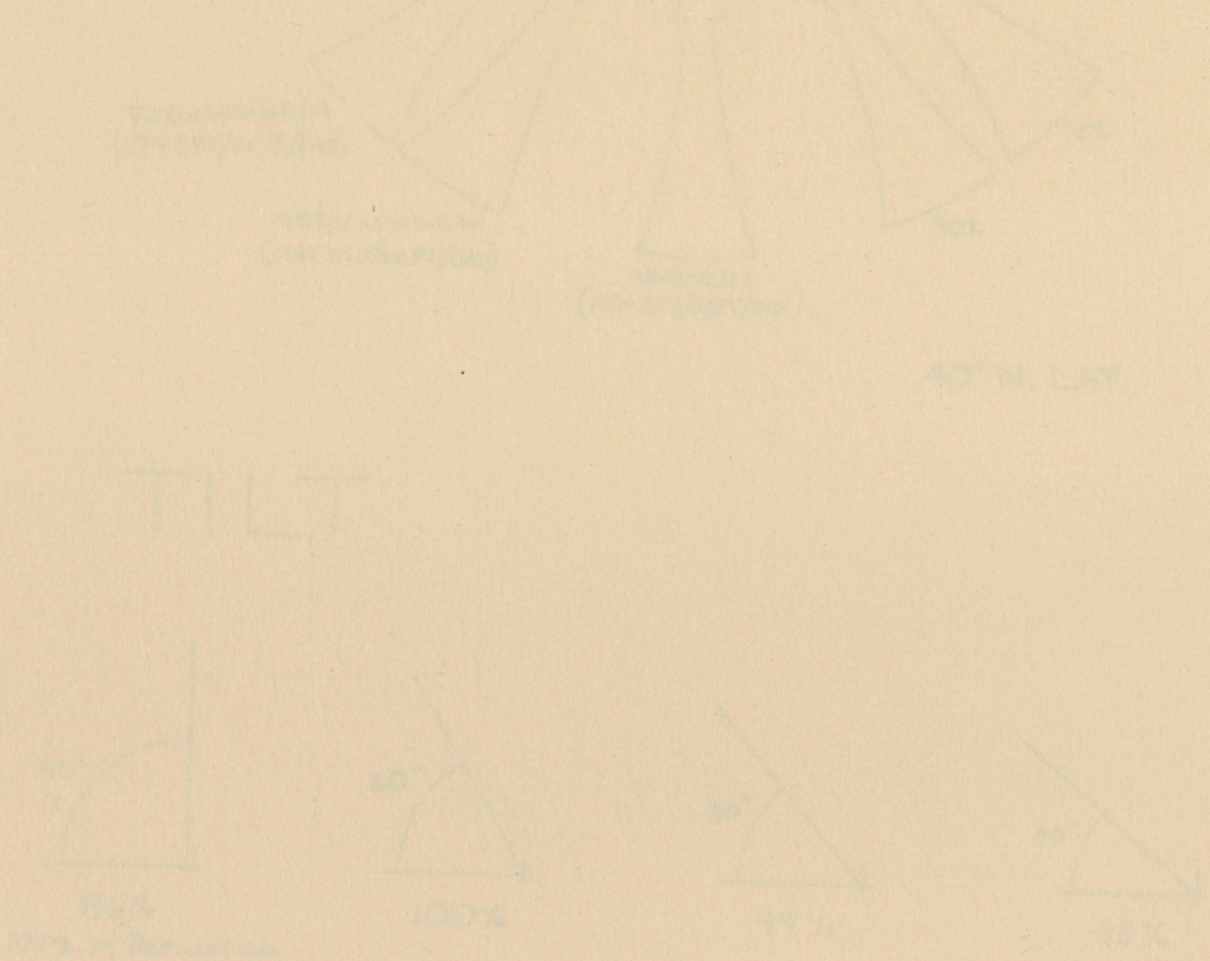
Why underground or partially underground? There are several reasons, beginning with protection against cold winter wind. The increased mass of the ground surrounding a building built underground slows down the temperature variations. If the floor is set deep in the earth, it will be located in the most stable earth temperature zone. This has an increased capacity to moderate temperature change, whether it be between daily

extremes or between seasonal extremes. The decision to build underground must be analysed to determine its benefits versus its economic drawbacks due to the high cost of excavation.

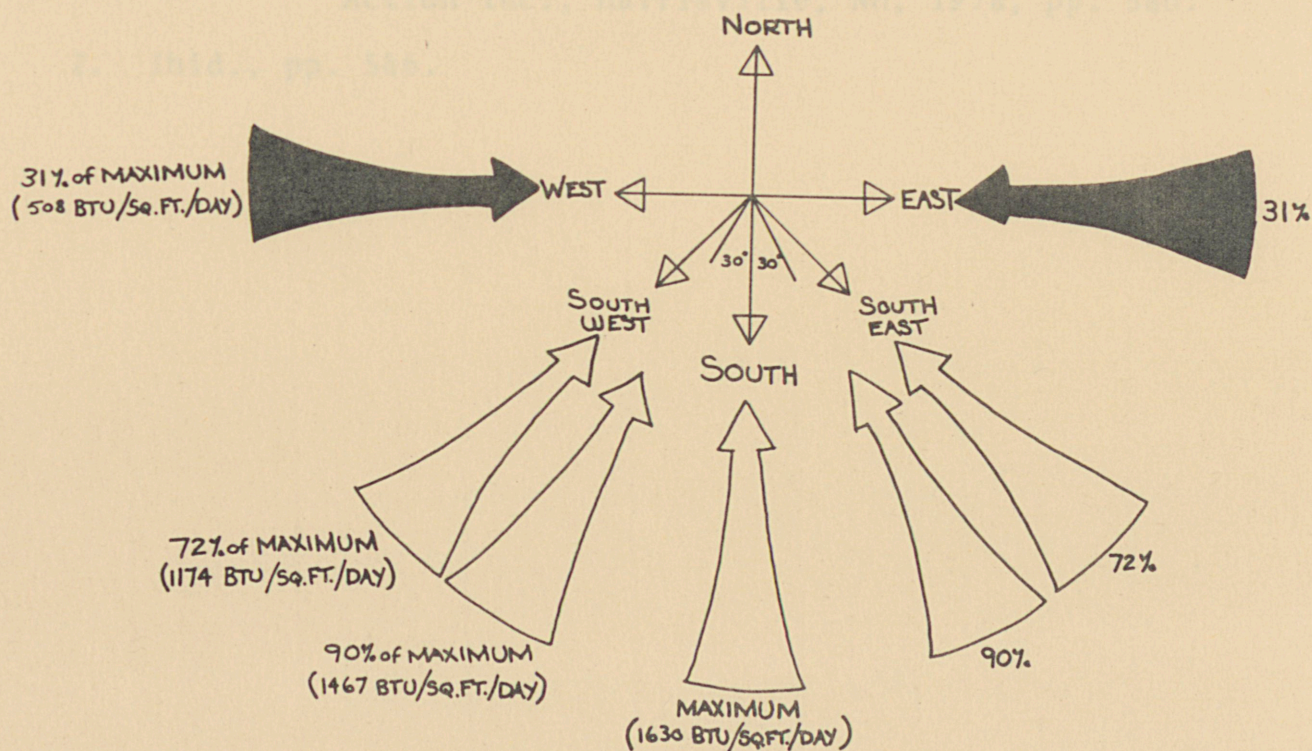
Components and equipment within a building are normally uncoordinated in that they function separately from one another. As a result, a large percentage of energy is transformed into waste heat. Integrating the mechanical systems into a central core or unit would reduce the inefficiencies that exist by allowing waste heat and water to be recycled. The collection of waste heat, the prevention of its dissipation, and the transfer of it back into the energy core, will maximize the overall system's efficiency. A central core also allows heat for space heating to be distributed with a great deal of versatility. Room layout and arrangement may be effected somewhat by this concept.

To "orient" means to correctly position in relation to the environment. Ideally a solar device should face due south. But it can work quite efficiently, during the heating season, even if it is not facing exactly south. According to Dan Scully,¹ vertical wall surface oriented as much as 30° east or west of south will still receive

90% of the maximum solar radiation striking a south facing wall. Like the orientation of a collecting surface, tilt also effects how much solar energy can be gathered. If a 60% tilt collects most solar energy, tilts as much as 20° to 30° from this optimum can still intercept over 90% of the available daily insolation per unit area. From a practical viewpoint, this suggests a considerable leeway in the design and positioning of solar devices. A look at the following figure, Orientation and Thermal Gain (after Dan Scully²) may help to visualize this.

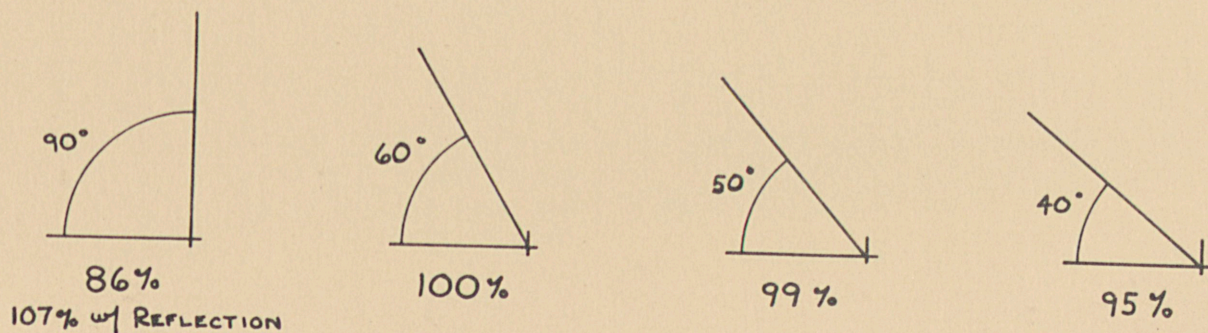


ORIENTATION AND THERMAL GAIN



40° N. LAT.

TILT



FOOTNOTES

1. Scully, Dan, The Fuel Savers, Total Environmental Action Inc., Harrisville, NH, 1978, pp. 5&6.
2. Ibid., pp. 5&6.

USER NEEDS

User Needs

Victor Olgyay (in Design With Climate¹) addresses many of the user's needs. He says the physical environment consists of many complex relationships. The occupant or user of a dwelling (the function of which is to support life and supplement livelihood) has basic needs which must be met. The user's requirements basic to life and comfort include, his physical and emotional needs as well as cultural factors such as moral and social elements. The shelter is the main instrument for fulfilling these requirements. It modifies the natural environment to approach optimum conditions of livability.

The user's physical needs include a controlled climatic environment, nutrition, hygiene, and areas or spaces in which to sleep, work and live, with adequate light and sound control. Ideally, the satisfaction of all needs appropriate to an occupants healthy or normal functioning would constitute the criterion of an environmentally balanced shelter.

First to be looked at should be the feeling of thermal balance, for without it, any definition of comfort is impossible. "The major elements of the climatic

environment which affect human comfort may be classified as air temperature, radiation, air movement and humidity."² The human body's metabolism produces heat and interchanges heat with it's climatic surroundings to maintain thermal stability. The bodily exchanges of heat can be classified in four main processes: radiation, conduction, convection, and evaporation.³ D. H. K. Lee⁴ summarized the factors involved with the thermal stability of the body in the following way:

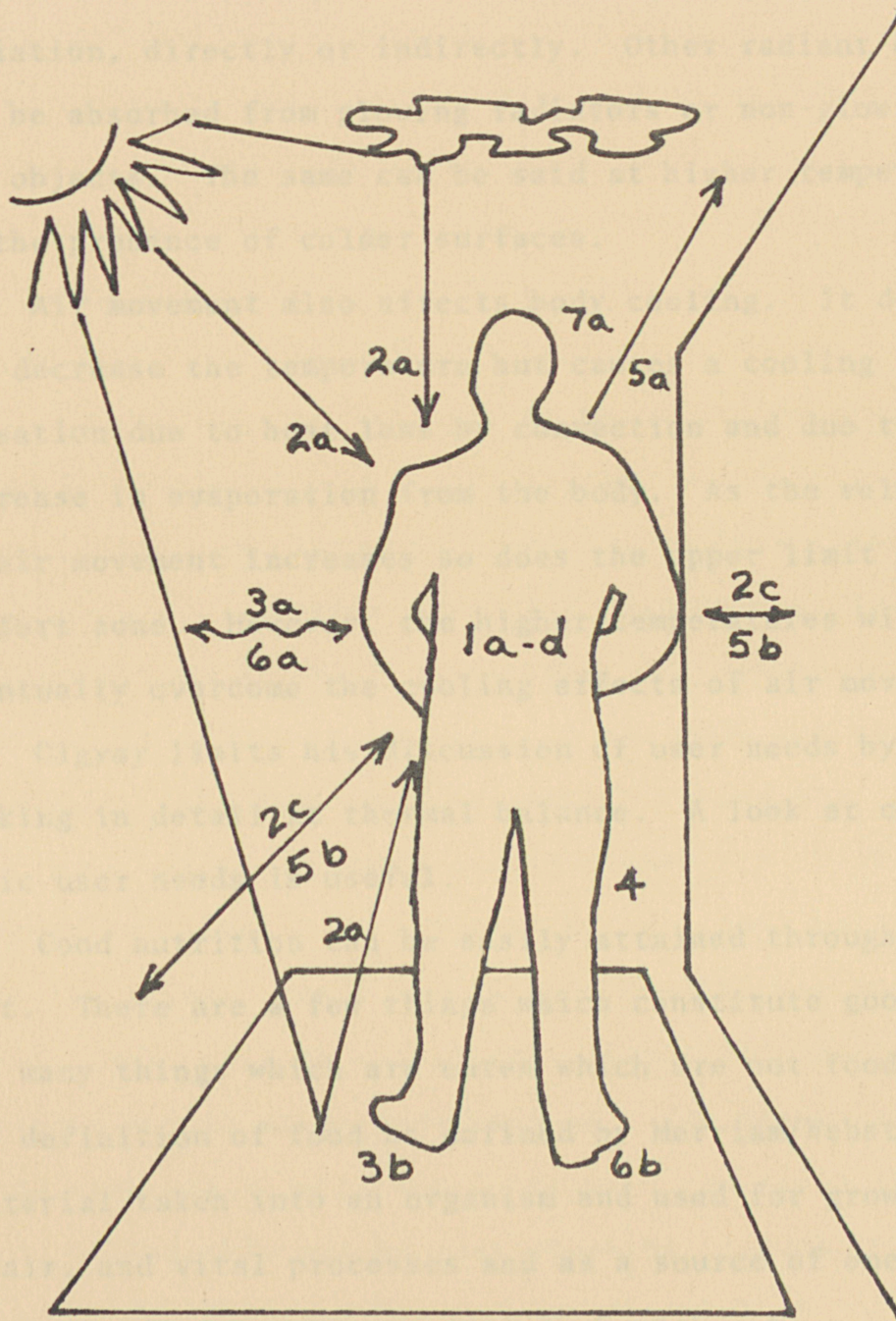
Gains

1. Heat produced by:
 - a) Basal processes
 - b) Activity
 - c) Digestive, etc. processes
 - d) Muscle tensing and shivering in response to cold
2. Absorption of radiant energy:
 - a) From sun directly or reflected
 - b) From glowing radiators
 - c) From non-glowing hot objects
3. Heat conduction toward the body:
 - a) From air above skin temperature
 - b) By contact with hotter objects
4. Condensation of atmospheric moisture (occasional):

Losses

5. Outward radiation:
 - a) To "sky"
 - b) To colder surroundings
6. Heat conduction away from the body:
 - a) To air below skin temperature (hastened by air movement convections)
 - b) By contact with colder objects
7. Evaporation:
 - a) From respiratory tract
 - b) From skin

The ideal air temperature would be a point where man is comfortable. This ideal temperature may differ with individuals, types of clothing, the nature of activity performed, sex, and age. The upper limit would be a temperature causing illness due to sunstroke or heatstroke. The lower limit would be when illness is contracted due to cold or at freezing point. The human being with a body temperature averaging 98.6°F would logically want a temperature zone halfway between what he can stand in cold without being uncomfortable and the point which would require real effort on the part of his circulatory and sweat secretion system to adapt to heat.⁵ "The human comfort zone ranges from 65° to 80°F at reasonable humidity levels."⁶



We can be comfortable at lower temperatures if the heat loss of the body is counteracted by the sun's radiation, directly or indirectly. Other radiant energy can be absorbed from glowing radiators or non-glowing hot objects. The same can be said at higher temperatures in the presence of colder surfaces.

Air movement also affects body cooling. It does not decrease the temperature but causes a cooling sensation due to heat loss by convection and due to the increase in evaporation from the body. As the velocity of air movement increases so does the upper limit of the comfort zone. However, the higher temperatures will eventually overcome the cooling effects of air movement.⁷

Olgyay limits his discussion of user needs by only looking in detail at thermal balance. A look at other basic user needs is useful.

Good nutrition can be easily attained through proper diet. There are a few things which constitute good food, and many things which are eaten which are not food at all. One definition of food as defined by Merriam/Webster is: "material taken into an organism and used for growth, repair, and vital processes and as a source of energy". No single food is able to sustain health, We require a

mixed and balanced diet. "A low energy diet aims at conserving energy--that is, taking the essential proteins, fats, carbohydrates, vitamins, minerals, enzymes and water directly from their source without wastage."⁸

These key elements are contained in most of the foods that you can grow and preserve yourself. Carbohydrates, vitamins, minerals, and dietary fiber can all be provided by raw fruits and vegetables, preferably fresh, and our need for protein and fats can be satisfied from plant or animal sources. Food only becomes part of the body after being dismantled by the action of teeth, saliva, gastric juices, enzymes, muscular movements of the intestines and absorption by the bloodstream. The processes of chemical breakdown and buildup in the body are called metabolism, the same process which produces body heat.

Good health is something many take for granted. A controlled climatic environment and a proper nutritional diet are a great start toward good health, but personal hygiene must also be considered. Facilities must be provided for an occasional wash-up. The basics would be of sink and shower, but a hot bath can clean the pores of the skin and be very relaxing -- even entertaining. A larger tub designed for soaking the whole family would

not only save water, but help break down social barriers which exist in this aspect of many families in our society.

The users' physical needs also include areas or spaces in which to work, sleep and live. Each area or space will have characteristics which will facilitate its function or functions. A kitchen, for instance, functions much in the same manner as a laboratory. The preparation of various foods requires washing, cutting, measuring, combining, heating and even experimenting with new ideas. The kitchen provides a place for the cooking process as well as storage for the various ingredients and utensils needed. The kitchen must be designed so that needed articles are easily accessible. Classified as a working space, there would be a higher light level than a bedroom for example. A bedroom is primarily a place to sleep, and low level light is needed. While sleeping one enjoys quiet and privacy. The bedroom can be a place to get away from the rest of the family. The various other areas or spaces also have differing functions that require special consideration in determining their characteristics.

The user's emotional needs are greatly effected by the characteristics of his habitat, such as, a quiet

and private place to rest. Another aspect of emotions which can be considered is the feeling of security.

The user of a dwelling that allows him to grow his own food and meet his other energy needs would have a secure feeling about the future. He would know where his meals and energy will come from without the dependence on a rapidly inflating or fluctuating economy. There are demands on his lifestyle, such as cleaning a fish rather than unwrapping it or spending a few hours a week in the greenhouse. But his self-acquired feeling of security would benefit him in the long run, as prices grow steadily higher because the demand for food and energy increases by his adversaries.

There are social and moral elements which could enter into the picture. If the user lives in one unit of a four unit complex which has a common source of electricity and a common food producing area, there must be a cooperative system in which each unit works their share toward a common goal. This would entail social interactions on a personal level in which the participants must all take pride in their work. This could help eliminate the feeling of being alienated from society, a definite problem in today's highly technological world.

A strong bond could develop as well as a sense of community between the various four family groups. This brings up a moral question. If things get relatively hostile in the future, with respect to food and fuel, then the self-sufficient community will appear rich compared to the neighboring community who is still plugged into the interstate web. Will the self-sufficient community be forced to up production to help their unfortunate neighbors, or will they simply go into mini-isolation to protect what they have? Hopefully the "we eat, they starve" dilemma will never come about between neighbors, as it already has between countries.

FOOTNOTES

1. Olgyay, Victor; Design With Climate, Princeton University Press, Princeton, New Jersey, 1963, p. 15.
2. Ibid., p. 15.
3. Ibid., p. 16
4. Lee, Douglas, H. K., Physiological Objectives in Hot Weather, U. S. Housing and Home Finance Agency, Washington, D.C., 1953, p. 2.
5. Op. cit., Olgyay, Paragraph paraphrased from, p. 17.
6. The A.I.A. Research Corporation, Regional Guidelines for Building Passive Energy Conserving Homes, U.S. Government Printing Office, Washington, D.D., p. 82.
7. Op. cit., Olgyay, Paragraph paraphrased from, p. 19.
8. Shore, John, Radical Technology, Random House, Inc., New York, 1976, p. 28.

Site Selection

The site is located in Belgrade, Montana within the Gallatin Valley. A regional site analysis was made of the northesast corner of the valley. It is taken from a previous project done for Architecture 231, Environmental Controls, November 1975. The analysis is included in the appendix. It deals with the geology, topography, hydrology, agriculture, vegetation, and climate of the area. From this study I found the entire planning area, except for the rough broken or mountain land to the north, is good to prime agricultural land. Large sections of marginally productive land extend one to two miles from Belgrade to the north, northwest, and west, sufficient for urbanization in the near future. The site selected is very adquate for my project.

Project Programming

PROJECT PROGRAMMING

Project Programming

There will be four single family units grouped together in a single structure. The various four family complexes are to form the framework of a residential community. Each residential grouping will have areas that are common to the four family group which are to provide a useful function, such as food production and house systems common to the four families. In addition to the common areas, each family will have its own unit in which privacy for the individual as well as the family will be considered.

Each four family complex will be sold to the four family group, with joint ownership of common areas and services and individual family ownership of particular family units. This will allow maximum flexibility within the family unit as well as some indication of the social responsibility for upkeep and service within the common areas. There must be understanding and cooperation with respect to common areas and work details involving food and electrical production and distribution. Joint ownership of the more expensive energy producing systems, such as wind powered electric generators, will reduce

the initial burden of the added cost over simply plugging into the Power Company.

The complex should develop an image as a leader in the community as an honest attempt to minimize waste and as a new approach in a living environment. The complex will work with nature and the natural processes rather than shutting them out. This concept suggests the use of natural materials which are indigenous to the valley and surrounding mountains. There will be no attempt to follow past trends in townhouse or condominium developments. Instead, a greater integration of four single family units to acquire a new social relationship among neighbors will be attempted. The various families will have a sense of unity within their four family groups. The various four family units will develop a sense of belonging to the overall project community.

Since this is a first attempt at a development of this nature in Belgrade I feel for the sake of public acceptance, the layout and room arrangement of the individual family units should resemble a conventional dwelling. The lifestyle of the families should be altered as little as possible while obtaining the degree of self-sufficiency desired. In future developments of

this nature, as public acceptance and understanding of a self-sufficient style of living comes forward a re-evaluation of the way people live, their activities, the way space is used, and the possibility of integration of various spaces to eliminate waste, will be necessary to further conserve resources.

Building Program (1 complex)

COMMON (X1) Approximate square footage to be determined

Mechanical Spaces
 Equipment Room
 Tanks (water)
 Rock storage
 Well room

Greenhouse (food gardens)
 Fish tanks
 Growing beds
 Suspended planters
 Circulation

Service Spaces
 Laundry
 Food processing

FAMILY UNIT (X4)

Mechanical Spaces
 Equipment Room
 Tanks
 Rock storage

Family Greenhouse (food garden)
 Fish tanks
 Growing beds
 Suspended planters
 Circulation

Residential Circulation
 Entry
 Halls
 Stairs & Landings

Living Spaces
 Living room - Dining room
 2 small bedrooms
 1 master bedroom

Service Spaces

Lavatory
 Bath (hot pool)
 Shower
 Kitchen
 Pantry (food storage)

Outdoor Spaces

Decks
 Wind generator

Systems Program

Wind powered electrical generation (D.C.)

Collection: each 4 unit complex (4 U.C.) will have a common wind generation installation.

Storage: Battery storage common to each 4 U.C.

Distribution: each unit will have a monitoring device to regulate usage in peak demand periods or during low supply periods.

- A.C. inverter to convert D.C. to A.C. is common to each 4 U.C.

- load sharing device to determine primary usage during low supply periods.

Direct solar gain

Collection: each unit and common area will use passive solar heating provided by a double shell convective loop with attached greenhouse.

Storage: thermal mass within the structure -- rock storage.

Auxiliary heating (wood)

Collection: group participation in wood gathering.

Storage: dividing of wood gathered for individual storage and consumption.

Distribution: radiant heat.

Water supply

Collection: pump located in well room of common areas.

Storage: common reservoir.

Distribution: if necessary each unit will have a monitoring device to regulate usage in peak periods or during low supply periods.

Food producing systems

- each unit will have a family greenhouse with a small agriculture system.
- common areas will have a larger greenhouse and an aqua-culture system with workload divided equally among family units. This area will have a food processing area with any excess production to be sold locally.
- areas provided for summer time gardening.

Waste handling

- methane digester located in common areas for treatment of domestic sewage and organic wastes.
- by-products of the digester to be used to provide nutrients for food producing systems.

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4. Jackle, William, *Whitehouse, Young, Street House, and Carlini, Sierra Club House*, San Francisco, California, 1971.
5. Kallay, Ted L., *Design with Nature*, Doubleday & Company, Inc., Garden City, New York, 1971.
6. New College Institute, *The Book of the New Alchemists*, E. P. Dutton, New York, 1973.
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8. Pacific Institute, *Energy Primer*, Pichea Park Press, Inc., Fremont, California, 1974.
9. Robinson, Gary D., *Design, People and Environmental Quality*, U. S. Department of the Interior, National Park Service, Washington, D.C., 1971.
10. Schiller, Dan, *The Total System, Total Environmental Action Inc.*, Harrisville, New Hampshire, 1974.
11. Steadman, Philip, *Energy, Environment and Building*, Cambridge University Press, Cambridge, 1970.
12. Taine, Richard S., *Architecture and Energy*, Anchor Press, New York, 1973.

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3. Fitch, James M.; American Building, Houghton Mifflin Company, Boston, 1972.
4. Leckie, Masters, Whitehouse, Young; Other Homes and Garbage, Sierra Club Books, San Francisco, California, 1975.
5. McHarg, Ian L.; Design with Nature, Doubleday & Company, Inc., Garden City, New York, 1971.
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14. Wampler, Louis; Underground Homes, 1978.
15. Wells, Malcolm; Energy Essays, Edmund Scientific Company, Barrington, New Jersey, 1976.
16. Wells, Malcolm; Underground Designs, 1977.

Periodicals

1. Stein, Richard G., "Architecture and Energy", Forum, July/August, p. 38, 1973.

APPENDIX

Table 1. Previous project done for Architecture III.
Environmental Controls, November, 1971.

BIOLOGICAL

4) Geological Map Diagram 111

REGIONAL SITE ANALYSIS

Taken from a previous project done for Architecture 231,
Environmental Controls, November, 1975.

BIOLOGICAL

A) Geological (see Diagram #1)

There are three basic areas derived from the glaciers and water deposits in the area. The first area consists of the unglaciated hills and Bridger mountains to the north and east of the site, which were possibly too high to have been overridden by the glaciers. The second area, lower in elevation and younger in Geologic time, is composed of Tertiary lake bed of Miocene and Oligocene sand, gravel and clay which have been tilted and faulted and include volcanic ash. During the formation of the Three Forks Structural Basin, of which the Gallatin Valley is a part, (see Diagram) through drainage was interrupted and many hundreds of feet of sediments derived from adjoining highlands and from falling volcanic ash. Tertiary strata constitute most of the valley fill. Resumption of drainage in the late Tertiary resulted in extensive erosion of these beds. This Alluvium, which consists of bottom lands, low terraces and glacial outwash sand and gravel, is the 3rd Area of geologic significance on the site. Alluvial fans of late Pleistocene Age extend into the valley deposited by streams that cut into fans of older alluvium on the higher slopes. (see geologic

Cross Section). In the vicinity of Belgrade this alluvium is at least 400' thick and due to its high coefficient of transmissibility is the principle aquifer beneath the valley floor.

The Valley's primary use was agriculture (see Diagram #3), but with urbanization came the need for limitations on Foundation (Diagram #4), Septic Disposal (Diagram #5), and Roads and Streets (Diagram #6).

Sources:

Physiography and Glacial Geology of Western Montana,
(U.S. Geological Survey Map of Montana).

Geology and Ground Water Resources of the Gallatin Valley,
Gallatin County, Montana, 1960.

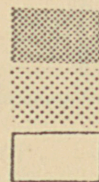
Soil Survey of the Gallatin Valley Area, Montana, Series
1931.



MAPS

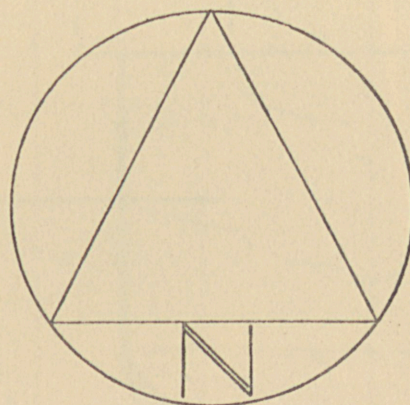
KEY

SEVERE
MODERATE
SLIGHT



SCALE

1" 62500'





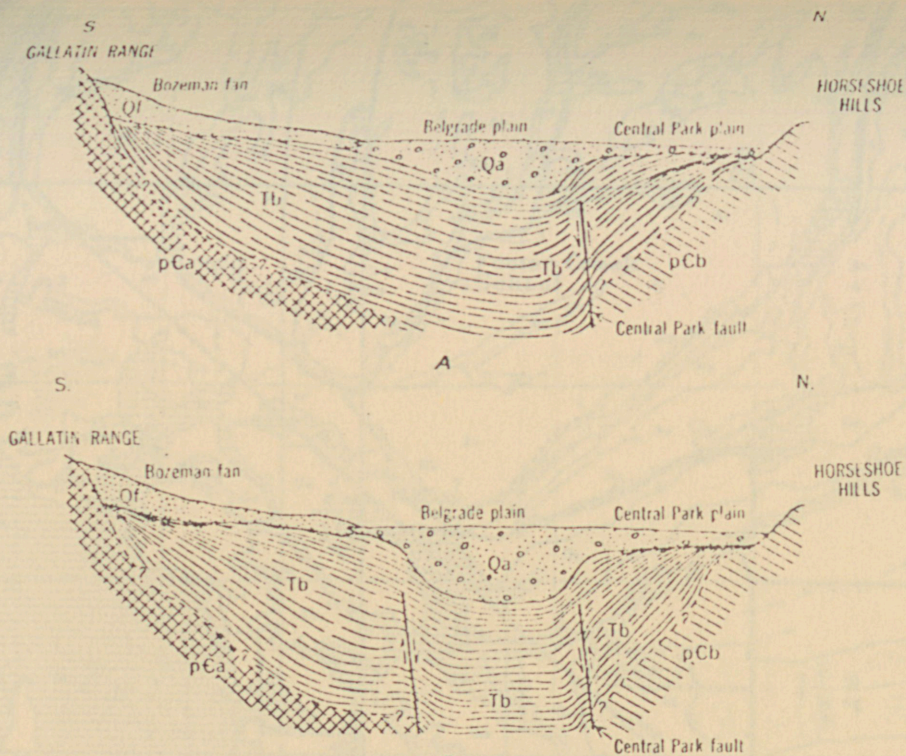
Central

Parr

Fault

1

Geology



EXPLANATION

Qf
Alluvium of
Quaternary age

Tb
Deposits of
Tertiary age

pCa
Precambrian metamorphic
rocks

Qf
Alluvial fan deposits
of Quaternary age

pCb
Belt series (Precambrian)

FIGURE 13.—Diagram showing alternative hypotheses for the formation of the Belgrade trough. A. By downwarping of the Tertiary strata northward toward the Central Park fault. B. By down dropping of block between the Central Park fault and a fault south of Belgrade.

3 FORKS STRUCTURAL BASIN

SOURCE:
ID-WATER RESOURCES, GALLATIN VALLEY, MONT.

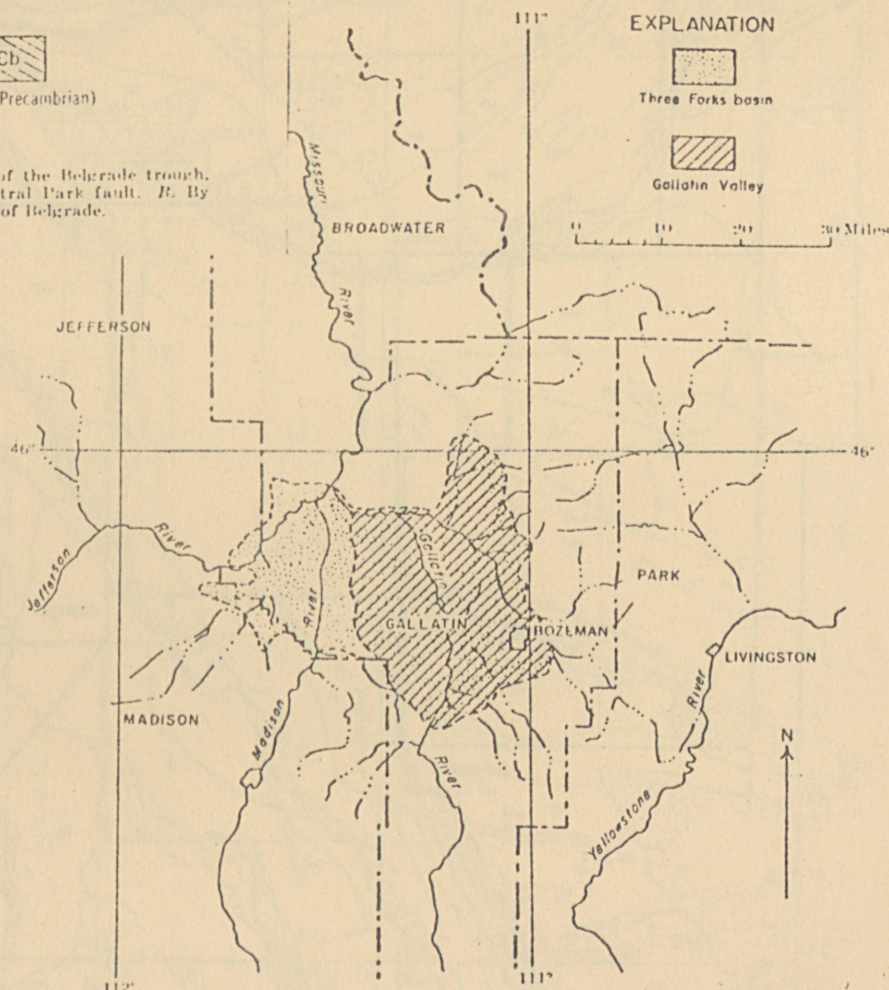
EXPLANATION

Three Forks basin

Gallatin Valley

0 10 20 30 Miles

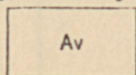
GEOLOGIC CROSS SECTION A



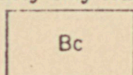


LEGEND

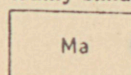
Amsterdam
very fine sandy loam



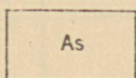
Bridger
silty clay loam



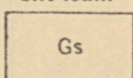
Manhattan
loamy sand



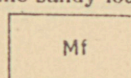
Amsterdam
silt loam



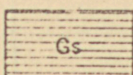
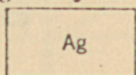
Gallatin
silt loam



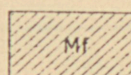
Manhattan
fine sandy loam



Ashuelot
gravelly loam

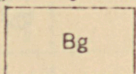


Swampy phase

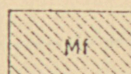
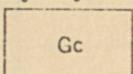


Gravelly subsoil phase

Beaverton
gravelly loam

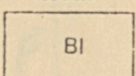


Gallatin
silty clay loam

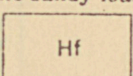


Smooth phase

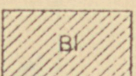
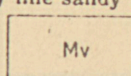
Beaverton
loam



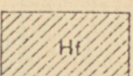
Havre
fine sandy loam



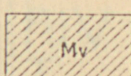
Manhattan
very fine sandy loam



Dark-colored phase

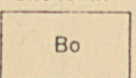


Dark-colored phase

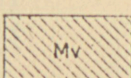
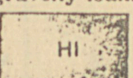


Colluvial phase

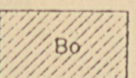
Bozeman
silt loam



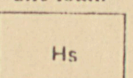
Huffine
gravelly loam



Shallow phase

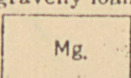


Brown phase

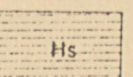
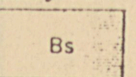


Huffine
silt loam

Manhattan
gravelly loam

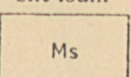


Bridger
stony loam



Poorly drained phase

Millville
silt loam



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G GRAZING
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 IRR INDUSTRIAL
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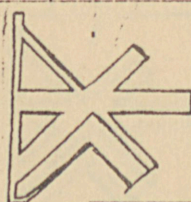
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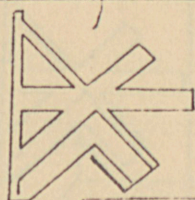
4



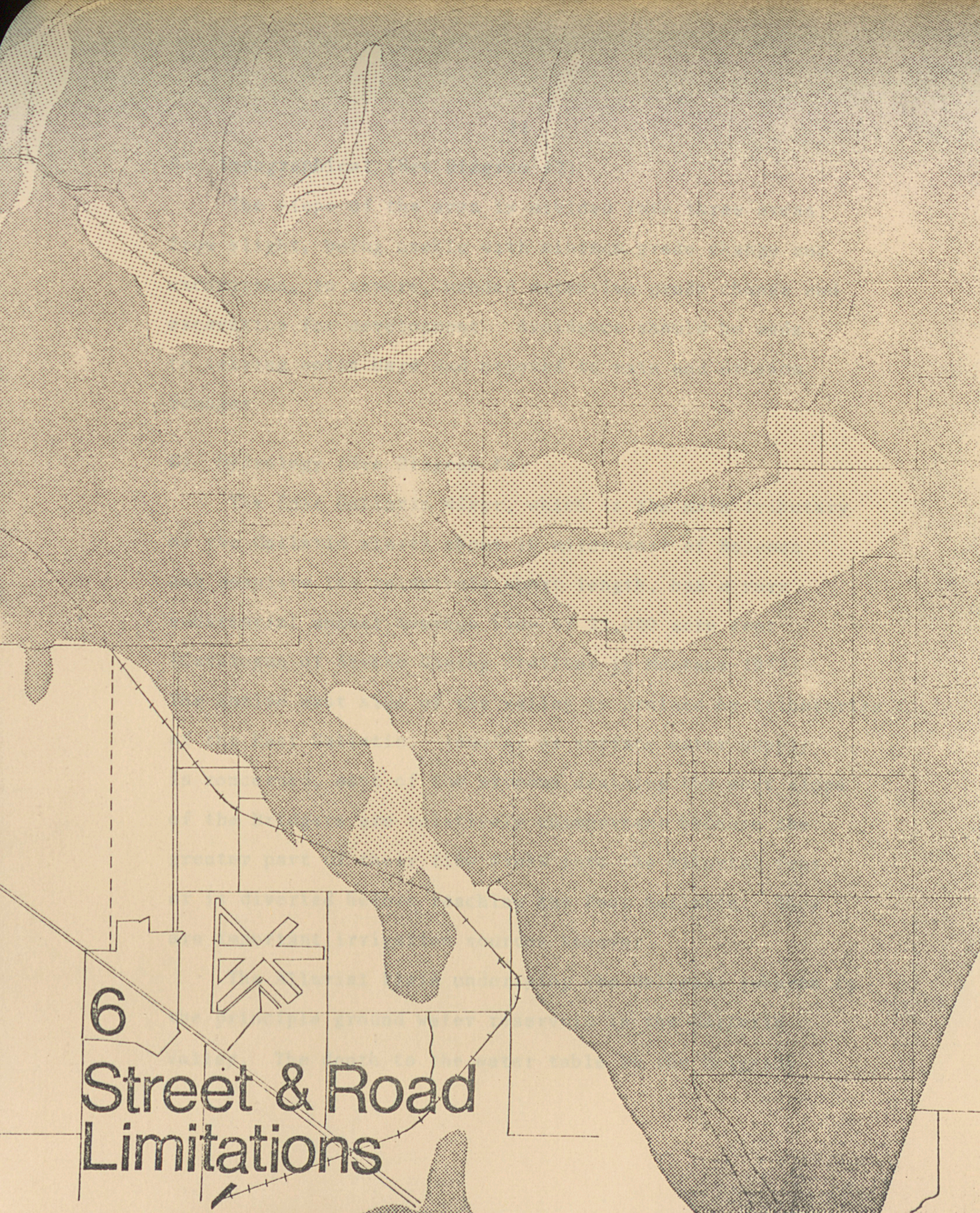
Building Foundation Limitations



5



Septic Tank Limitations



6

Street & Road Limitations

B) Topographical (See Diagram #7)

The slope of the area is divided into three areas from slight, being usable with minimum grade change and excavation, to severe, needed extensive grade change and excavation for development. Avoidance should be made to leaving soils bare and exposed to rain and erosion damages.

C) Hydrology (See Diagram #8)

The East Gallatin River, which is the main tributary of the Gallatin starts about 10 miles east of Bozeman and despite its relatively short length, has a very substantial annual average flow of 26,000 acre feet (Catalogue of Stream Gaging Stations in Montana 1972). The entire east side of the valley is drained by tributaries of the East Gallatin. Insofar as surface water supply is concerned, most of the streams draining the west slope of the Bridgers are relatively unimportant because the greater part of their flow sinks into the alluvial fans or is diverted before reaching the East Gallatin. They are important irrigation sources however.

The Alluvial Plain underlying the Belgrade subarea is the principle ground water reservoirs in the Gallatin Valley. The depth to the water table in the Belgrade





Dry Creek Church

Reese Creek School

Springhill Church

Springhill

Gallatin Airfield

7

Slope

vicinity is also somewhat greater than elsewhere in the valley. At its highest seasonal position it may be forty feet below ground level. Throughout most of the rest of the area between the Gallatin and East Gallatin the water table is within thirty feet of ground level and in many places is within ten feet of the surface.

The groundwater reserve of Gallatin Valley is recharged principally by infiltrating stream and irrigation water and only a small part is affected by direct infiltration from precipitation and snowmelt. The general groundwater movement is from the edges to the center of the valley and in a northward direction.

Almost all the water currently pumped from wells in the valley is used for domestic or livestock-agriculture supply. This quantity at present is small compared to the total volume of groundwater, however, significant increases in usage would inevitably tax the available supply.

Three types of ground waters are shown in the diagram #8. 0-6 inches under surface is a severe area and should be controlled from pollution, with 6-10 inches being moderate which should be checked depending on soil types. The flood plain is shown and should be given

strong consideration in design process. It will save dollars and lives if urban development is made outside of this area, and used for parks and recreation with low density.

Sources:

Geology and Ground Water Resources of the Gallatin Valley, Gallatin County, Montana, 1960.

Soil Survey of the Gallatin Valley Area, Montana, Series 1931.

U. S. Geological Survey Map of the Gallatin Valley, Montana.

Belgrade Master Plan, 1973.



East

Gallitan

River

Bear

Creek

Creek

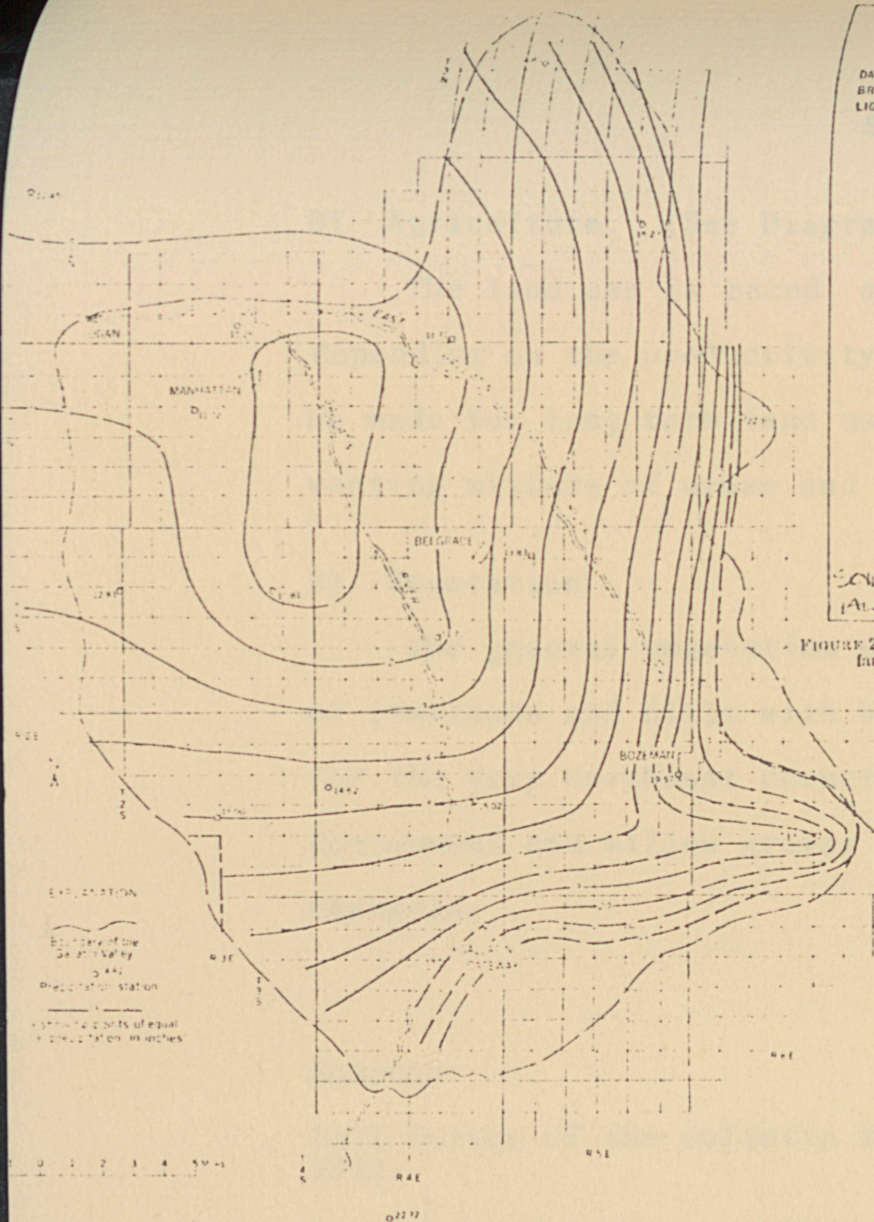
Reese

Middle

Cottonwood

Creek

water less than 10'
under ground &
well • location



GALLATIN VALLEY PRECIPITATION ▲

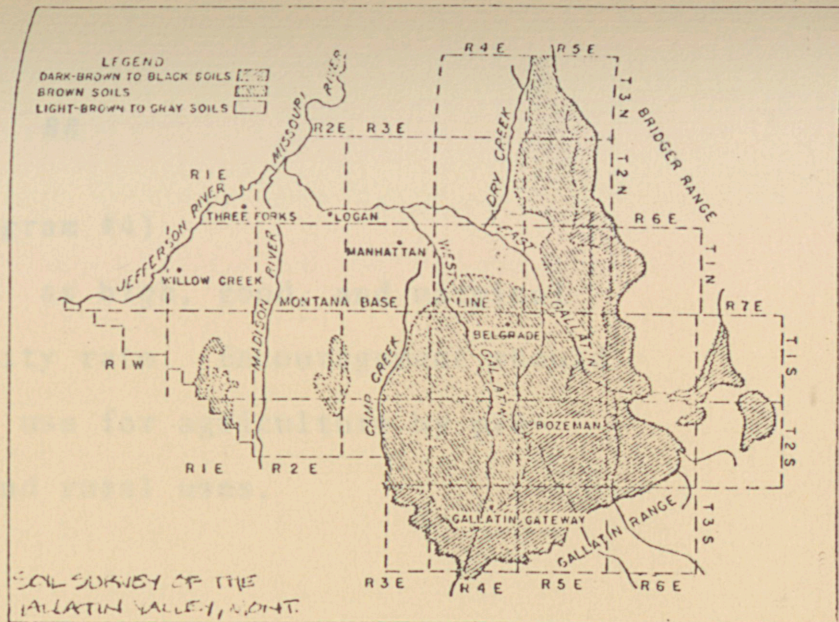


FIGURE 2.—Sketch map of the Gallatin Valley area, Mont., showing the three subgroups of well-drained farming soils. Note that the dark-brown to black soils lie adjacent to the mountain ranges.

FARMING SOIL SUBGROUPS ▲

GALLATIN VALLEY ALLUVIUM ▼

SOURCE:
GEOLOGY, GROUND-WATER RESOURCES, GALLATIN VALLEY, MONT.

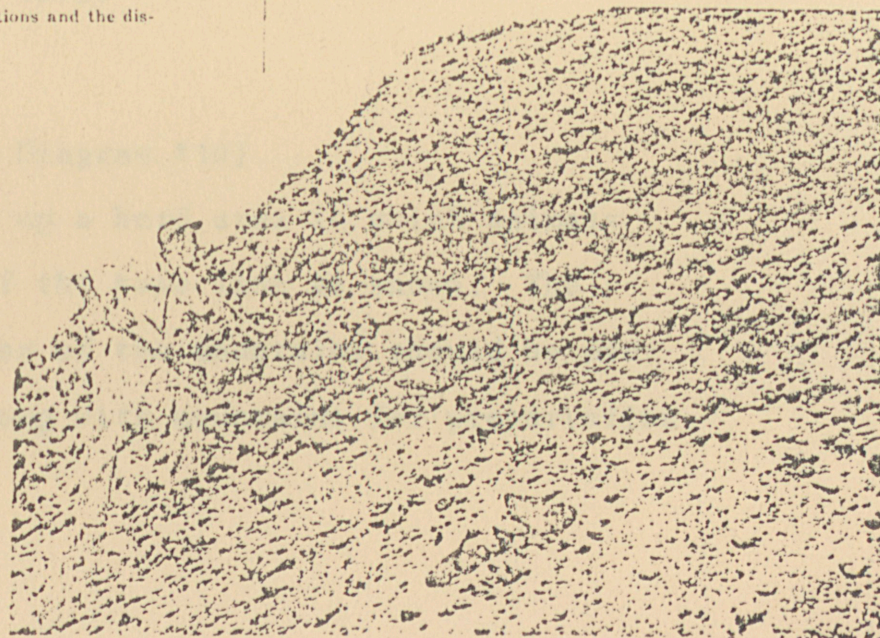


FIGURE 9.—Younger alluvium in the Gallatin Valley. Stream-channel deposits in the SW 1/4 Sec. 7, T. 1 S., R. 5 E.

D) Agriculture. (See Diagram #4)

The land use is rated as high, good, and marginal depending on the productivity rate. Encouragement should be made for long term land use for agriculture by preventing mixture of urban and rural uses.

E) Vegetation

The general vegetation pattern is grassland cover of flatlands and hills with brush and evergreen timber for the very northeast corner of the study area. Cottonwood and willow groves border the major stream channels.

Sources:

Soil Survey of the Gallatin Valley Area, Montana, Series 1931.

Belgrade Master Plan, 1973.

F) Preservation (See Diagram #10)

Belgrade has set up a herd area in which animals are protected south of the base line as shown. The swampy land at the base of the mountains should be preserved for feeding along with mountains for preservation.

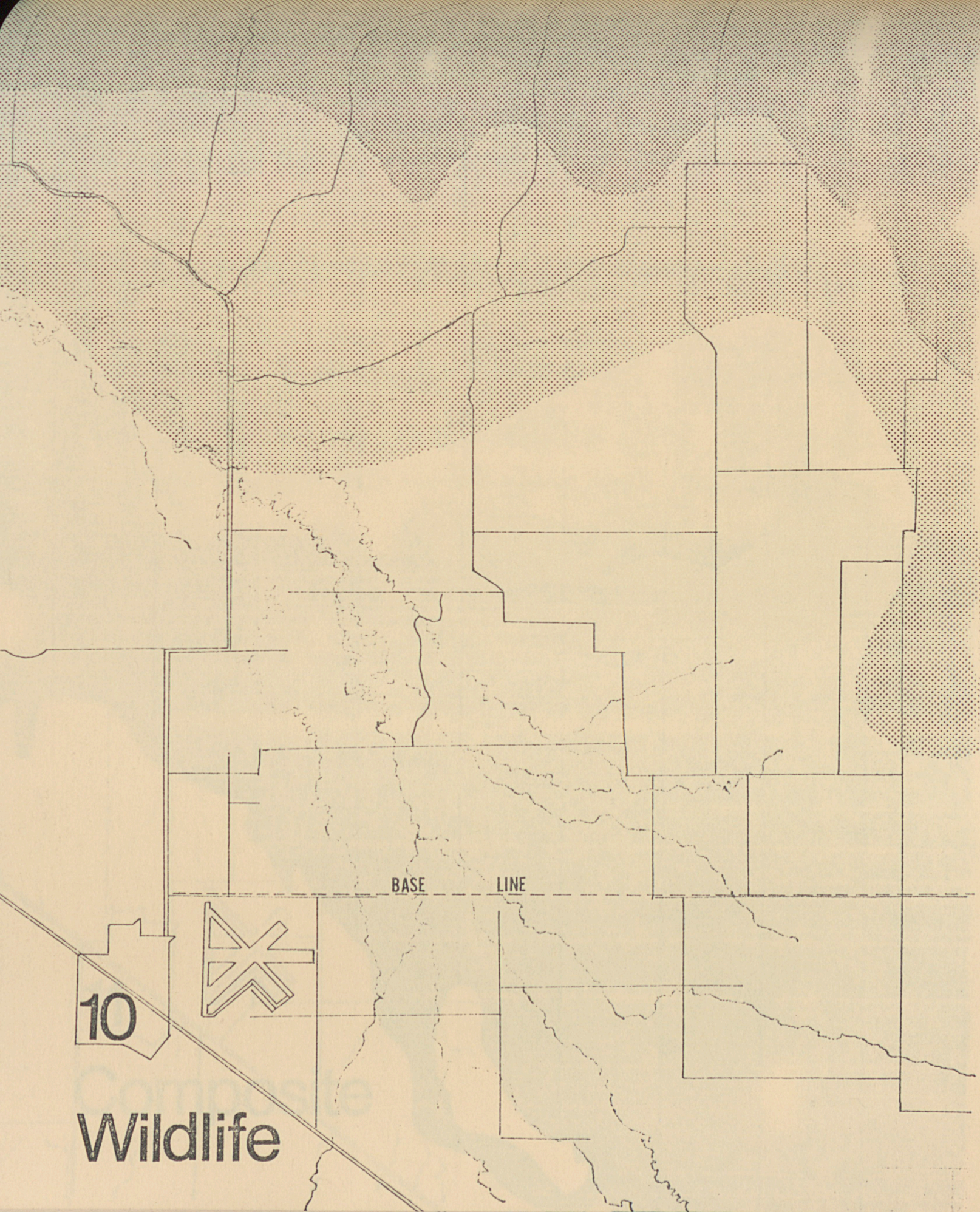
This area will have a constant barrier from Belgrade and human habitat in the valley as long as the recommended prime to moderate farming land remains.

All streams in the Belgrade area are very heavily stocked with fish and are extremely clean waters. This environment should remain at a constant level with severe futuristic views on pollution control. The city should strongly urge non-pollution industry that will not change the eco-system of the rivers.

G) Summary (See Diagram #11)

The entire planning area except for the rough broken or mountain land to the north is good to prime agriculture land. Large sections of marginal productive land extends one to two miles from town to the north, northwest, and west, sufficient for urbanization in the near future.

Sources: Derived from previous studies.



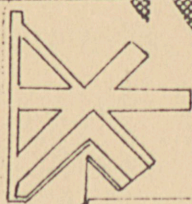
BASE LINE

10

Wildlife

11

Composite



CLIMATOLOGY

Climatology data is presented on the following charts.

NORTH DIRECTION

PREVAILING
WINDS AND
PRECIPITATION
DAYTIME

STRONGER WINDS
DAYTIME

WINTER
AND NIGHT
WINDS

MEAN ANNUAL WIND SPEED 6.4 mph

SOURCES

SOIL SURVEY OF THE CAL-LATE VALLEY WITH MONTANA 1931 AS
SELECTIVE ANNUAL MEASUREMENTS

WIND ANALYSIS

CALM DAYS
NORTH BREEZES

N

PREVAILING
WINDS AND
PRECIPITATION
DAYTIME

W-

STRONGER WINDS
DAYTIME

-E

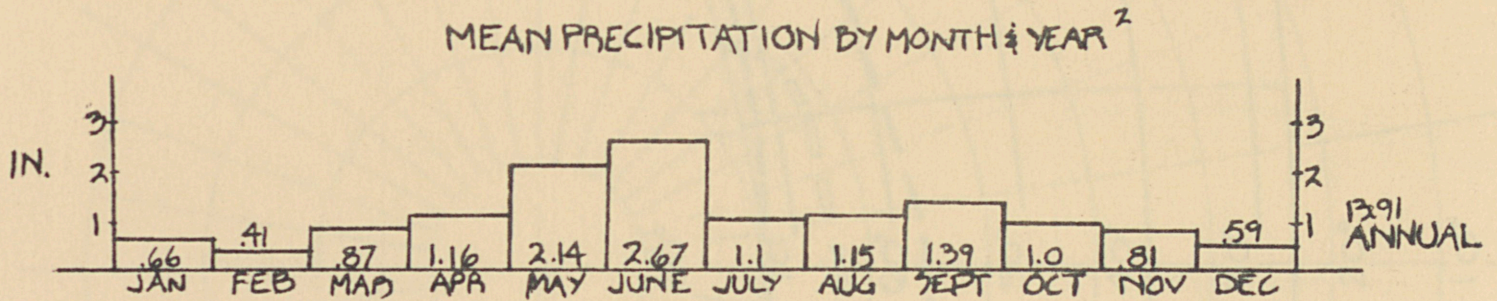
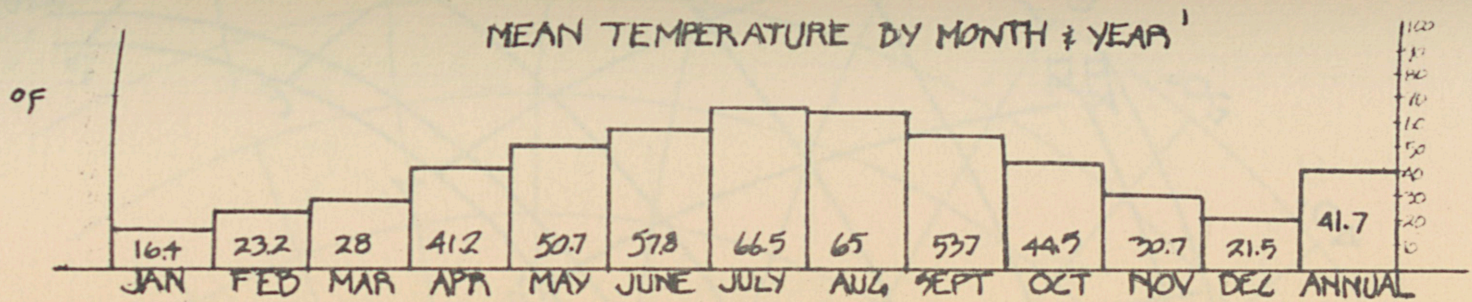
WINTER
AND NIGHT
WINDS

S

MEAN ANNUAL WIND SPEED 6.4 mph

SOURCES

SOIL SURVEY OF THE GALLATIN VALLEY AREA, MONTANA 1931 p.5
SUBJECTIVE AIRPORT PERSONNEL OBSERVATIONS



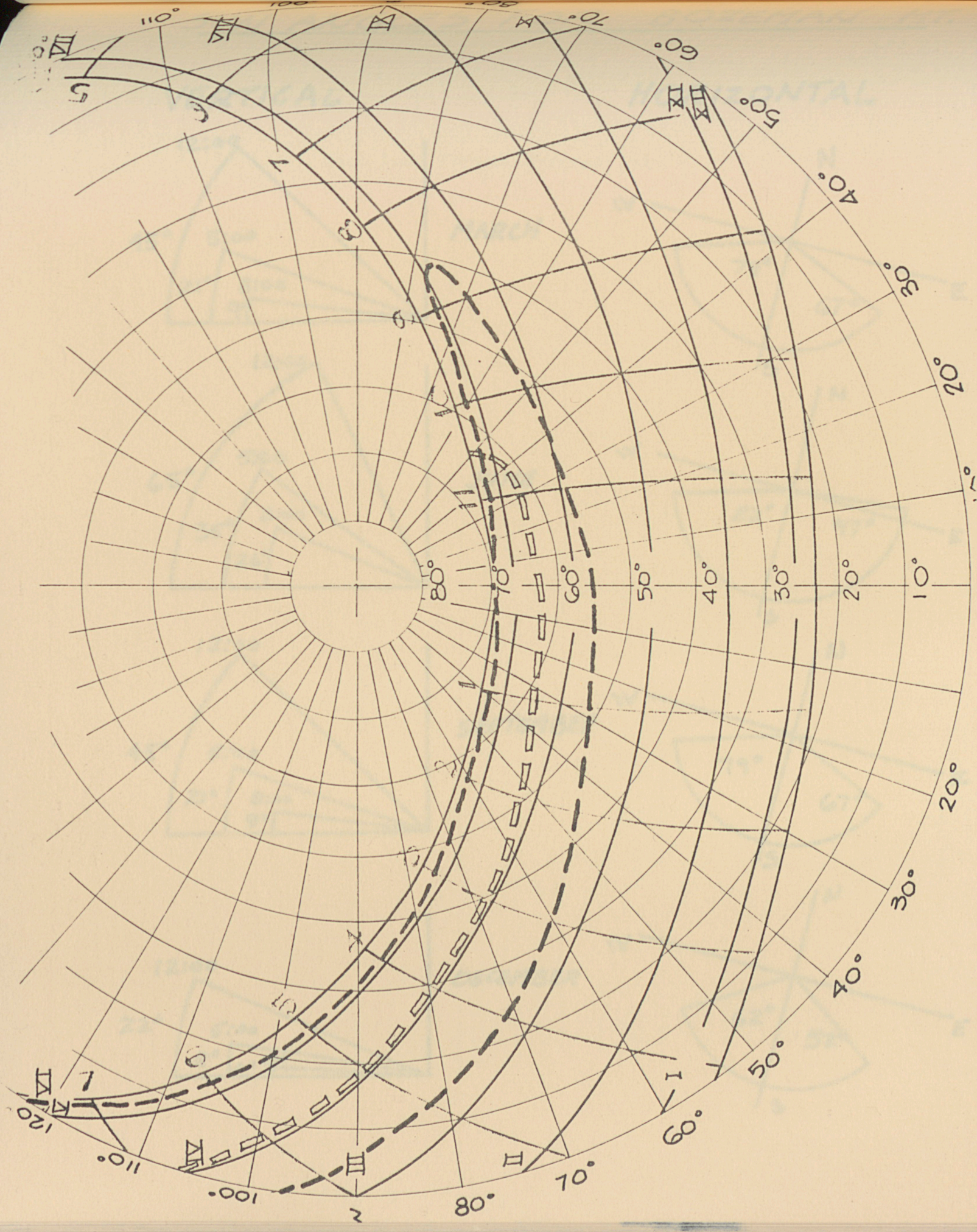
TEMPERATURE EXTREMES³

LAT. ° '	ELEV. FT.	WINTER				SUMMER						
		MEDIAN OF ANNUAL EXTREMES	99%	97%	COINCIDENT WIND VELOCITY	DESIGN DRY BULB			OUT DOOR DAILY RANGE	DESIGN WET BULB		
						1%	2 1/2%	5%		1%	2 1/2%	5%
45 5	4856	-25	-15	-11	LOW	88	85	82	32	61	60	59

SOURCES

1 & 2 CLIMATOLOGICAL DATA U.S. DEPT OF COMMERCE

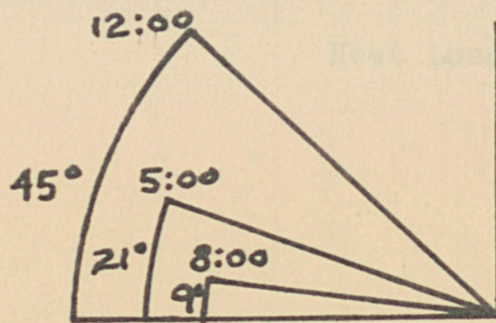
3 ASHRAE GUIDE & DATA BOOK 1973 P.679



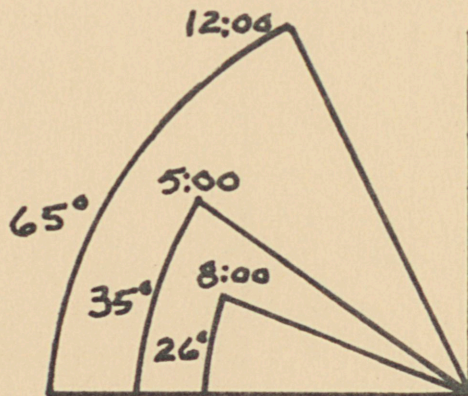
SUN ANGLES FOR BOZEMAN MT.

VERTICAL

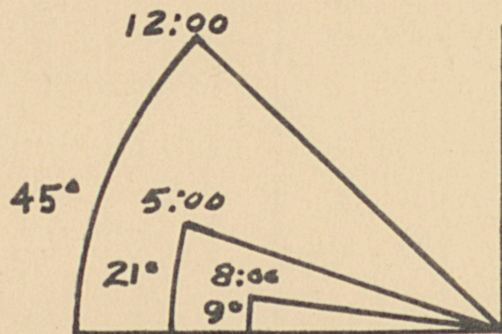
HORIZONTAL



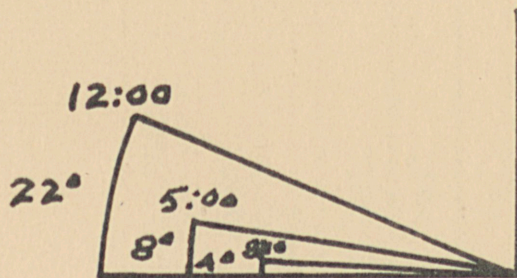
MARCH



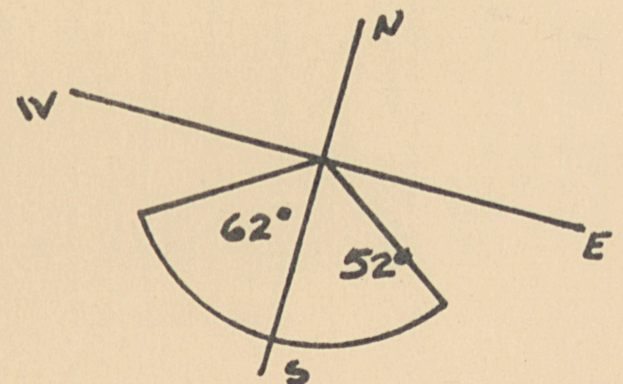
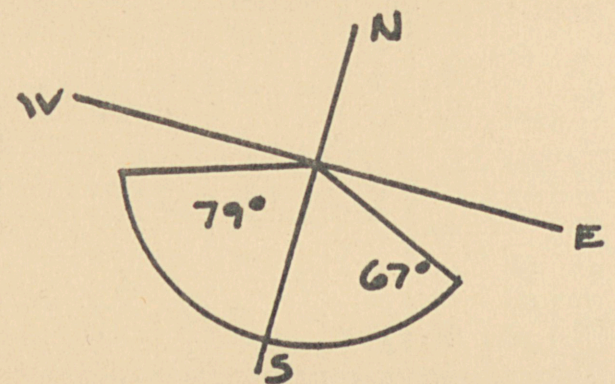
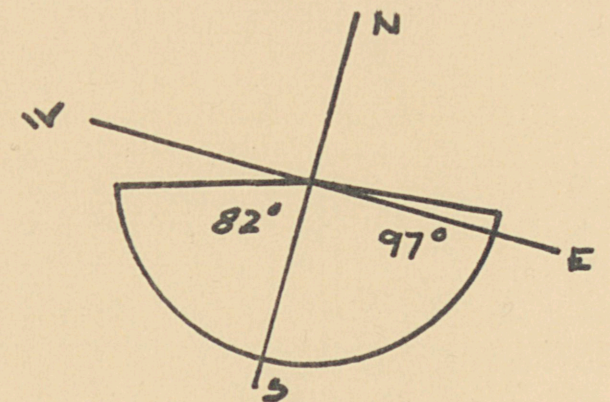
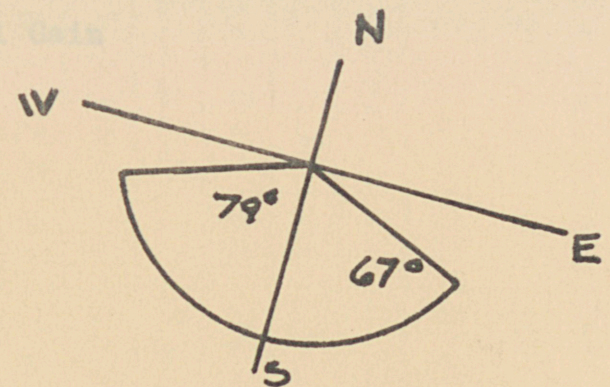
JUNE



SEPTEMBER



DECEMBER



Thermal Balance

Heat loss (Btu)	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Gain cycle (8hr.)						
Roof	14,916	18,917	21,092	18,178	16,091	10,350
N. wall	16,916	21,453	23,919	20,615	18,248	11,738
S. wall	101,006	128,099	142,823	123,093	108,957	70,086
E. wall	10,155	12,879	14,359	12,376	10,954	7,046
Floor	38,280	38,280	38,280	38,280	38,280	38,280
sub total	181,273	219,628	250,473	212,542	192,530	137,500
Loss cycle (16hr.)						
Roof	14,120	17,907	19,965	17,207	15,231	9,797
N. wall	13,373	16,960	18,908	16,297	14,426	9,279
S. wall	47,965	60,831	67,823	58,453	51,741	33,281
E. wall	10,415	13,209	14,727	12,692	11,235	7,227
Floor	14,438	14,438	14,438	14,438	14,438	14,438
sub total	100,311	123,345	135,861	119,087	107,071	74,022
Infiltration (24hr.)	234,829	297,816	332,047	286,177	253,314	162,943
total	516,413	640,789	718,381	617,806	552,915	374,465
Thermal gain (Btu)	888,768	810,770	907,943	1,028,962	1,017,905	883,601
Thermal Balance (Btu)	+372,355	+169,981	+189,562	+411,156	+464,990	+509,136

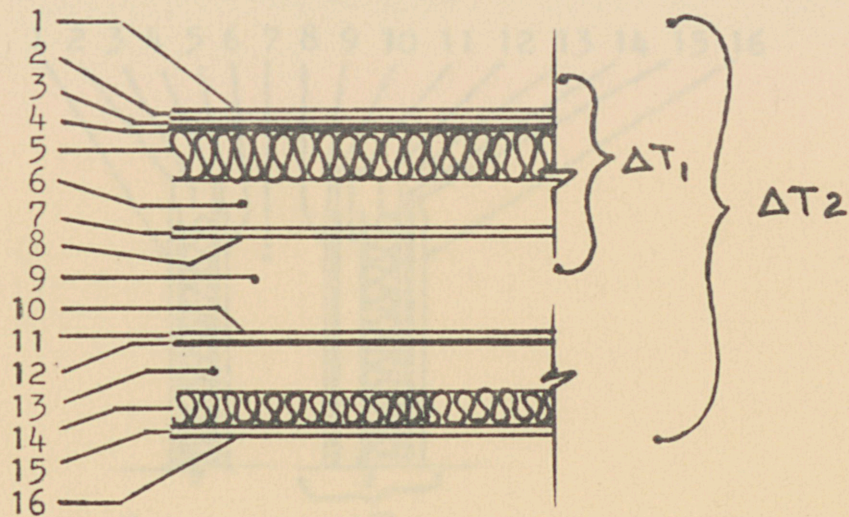
Surface areas (ft²)

Gain cycle -- ΔT_1 -- Buffer space to outside
(8hr.)

Loss cycle -- ΔT_2 -- Inside to outside
(16hr.)

	ΔT_1	ΔT_2
Roof	1200	960
North wall	626	546
windows	33	33
door	21	21
South wall		
50% glass - rock		380
50% glass - glass		380
windows	630	
other structure	100	
End wall	612	408
windows	18	18
Below grade		960
floors	1440	
walls	760	

100
Roof



direction of heat flow -----> (R)

1	outside surface (15 MPH wind)	0.17
2	built up roof	0.33
3	3/4" decking	0.93
4	building paper	0.06
5	6" fiber insulation	19.00
6	6" air space	0.90
7	3/8" plywood	0.47
8	inside surface	0.68
9	12" air space	0.85
10	inside surface	0.68
11	3/8" plywood	0.47
12	building paper	0.06
13	6" air space	0.90
14	4" fiber insulation	12.48
15	1/2" gyp. board	0.45
16	inside surface	0.62

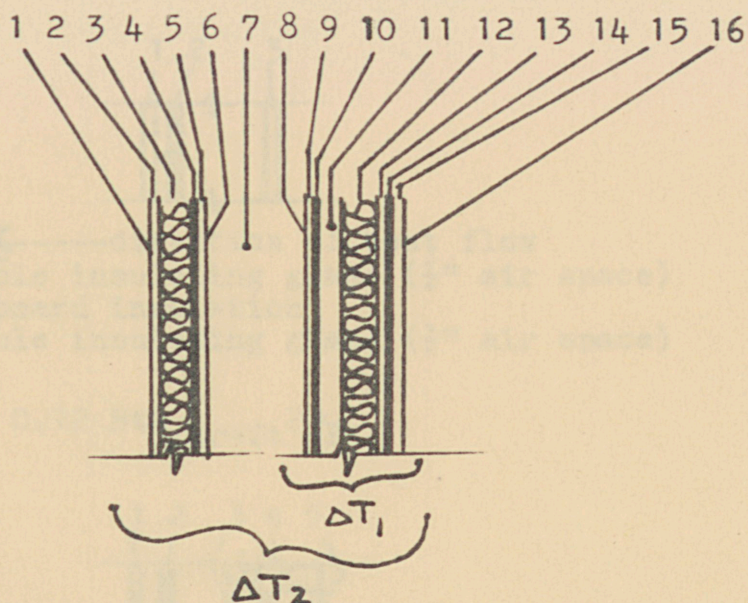
$$\Delta T_1 \quad R = 22.08 \text{ hr-ft}^2\text{-}^\circ\text{F/Btu}$$

$$U = .0453 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

$$\Delta T_2 \quad R = 37.29 \text{ hr-ft}^2\text{-}^\circ\text{F/Btu}$$

$$U = .0268 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

North wall



direction of heat flow ----->

(R)

1	inside surface	0.68
2	½" gyp. board	0.45
3	4" fiber insulation	12.48
4	building paper	0.06
5	3/8" plywood	0.47
6	inside surface	0.68
7	12" air space	0.94
8	Inside surface	0.68
9	3/8" plywood	0.47
10	building paper	0.06
11	2" dead air	0.94
12	4" fiber insulation	12.48
13	wood sheathing 25/32"	0.98
14	building paper	0.06
15	wood siding ½"-8" lapped (avg. R)	0.85
16	outside surface (15 MPH wind)	0.17

$$\Delta T_1 \quad R = 16.69 \text{ hr-ft}^2 \text{ } ^\circ\text{F} / \text{Btu}$$

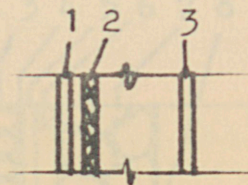
$$U = 1/R = .0599 \text{ Btu/hr-ft}^2 \text{ } ^\circ\text{F}$$

$$\Delta T_2 \quad R = 32.45 \text{ hr-ft}^2 \text{ } ^\circ\text{F} / \text{Btu}$$

$$U = .0308 \text{ Btu/hr-ft}^2 \text{ } ^\circ\text{F}$$

South wall

loss cycle

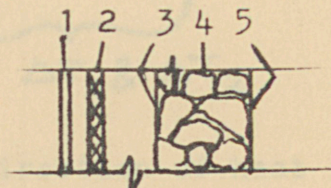
 ΔT_2 

←-----direction of heat flow

- | | | |
|---|--|-------------|
| 1 | double insulating glass ($\frac{1}{2}$ " air space) | (R) |
| 2 | 1" board insulation | 1.72 |
| 3 | double insulating glass ($\frac{1}{2}$ " air space) | 5.26 |
| | | <u>1.72</u> |
| | | 8.68 |

(R)
1.72
5.26
1.72
8.68

$$U = 0.12 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$



←-----direction of heat flow

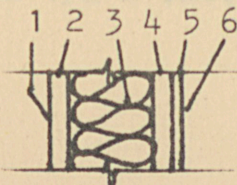
- | | | |
|---|--|------------|
| 1 | double insulating glass ($\frac{1}{2}$ " air space) | (R) |
| 2 | 1" board insulation | 1.72 |
| 3 | inside surface | 5.26 |
| 4 | 12" rock | .68 |
| 5 | inside surface | .78 |
| | | <u>.68</u> |
| | | 9.12 |

(R)
1.72
5.26
.68
.78
.68
9.12

$$U = 0.11 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

Other structure

Gain cycle

 ΔT_1 

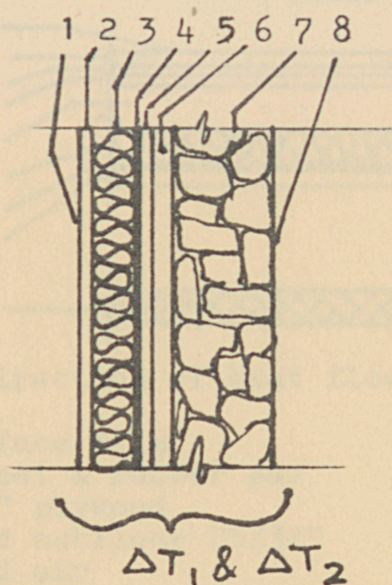
←-----direction of heat flow

- | | | |
|---|-----------------------------|-------------|
| 1 | Outside surface | (R) |
| 2 | 2"wood | 0.17 |
| 3 | 10" insulation | 2.00 |
| 4 | 2"wood | 31.00 |
| 5 | finish wood $\frac{1}{2}$ " | 2.00 |
| 6 | inside surface | 0.81 |
| | | <u>0.68</u> |
| | | 36.66 |

(R)
0.17
2.00
31.00
2.00
0.81
0.68
36.66

$$U = 0.027 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

End wall



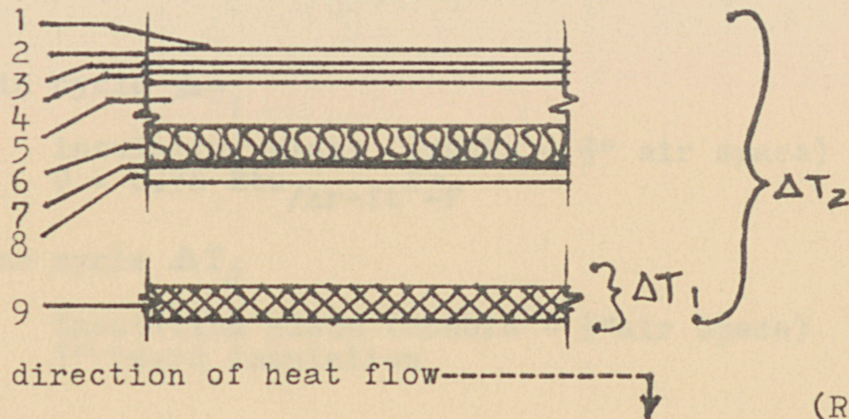
direction of heat flow -----> (R)

1	inside surface	0.68
2	$\frac{1}{2}$ " gyp. board	0.45
3	6" fiber insulation	19.00
4	building paper	0.06
5	$\frac{3}{8}$ " plywood	0.47
6	2" dead air	0.94
7	12" rock	0.78
8	outside surface	0.17

$$\Delta T_1 \text{ \& } T_2 \quad R = 22.55 \text{ hr-ft}^2\text{-F/Btu}$$

$$U = 1/R = .044 \text{ Btu/hr-ft}^2\text{-F}$$

Floor



	(R)
1 surface film	0.61
2 carpet & rubber pad	0.81
3 5/8" plywood	0.78
4 wood subfloor 25/32"	0.98
5 dead air	1.23
6 3" fiber insulation	11.00
7 building paper	0.06
8 1/2" plywood	0.62
9 2"ridg. insulation (waterproof)	10.52

$$\Delta T_1 \quad R = 11.49 \text{ hr-ft}^2\text{-F/Btu}$$

$$U = .087 \text{ Btu/hr-ft}^2\text{-F}$$

$$\Delta T_2 \quad R = 26.60 \text{ hr-ft}^2\text{-F/Btu}$$

$$U = .0376 \text{ Btu/hr-ft}^2\text{-F}$$

Windows

Gain cycle ΔT_1 insulating glass (double - $\frac{1}{2}$ " air space)

$$U = 0.58 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

Loss cycle ΔT_2 insulating glass (double - $\frac{1}{2}$ " air space)

3" board insulation

(R)

1.72

15.78

17.50

$$U = 0.057 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

Doors

Both cycles ΔT_2 & T_1 1 $\frac{1}{2}$ " solid wood with wood storm door
(50% glass)

$$U = 0.27 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

Cycle: GAIN

HEAT LOSS

Duration: 8 hr.

Ti = 65°F		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
(To)	Mean Temp.	30.7	21.5	16.4	23.2	28.0	41.2
ΔT (Ti - To)		34.3	43.5	48.5	41.8	37.0	23.8
NORTH WALL 626 ft. ²							
U = 0.0599 Btu / hr.-ft ² -°F							
q" -- Btu/hr.-ft ²		2.05	2.61	2.91	2.50	2.22	1.43
q -- Btu/hr.		1,286.2	1,631.1	1,818.6	1,567.4	1,387.4	892.4
Sub total -- Btu		10,289	13,049	14,549	12,539	11,099	7,140
WINDOWS 33 ft. ²							
U = 0.56 Btu/hr.-ft ² -°F							
q" -- Btu/hr.-ft ²		19.21	24.36	27.16	23.41	20.72	13.33
q -- Btu/hr.		633.9	803.9	896.3	772.5	683.8	439.8
Sub total -- Btu		5,071	6,431	7,170	6,180	5,470	3,519
DOOR 21 ft. ²							
U = 0.27 Btu/hr.-ft ² -°F							
q" -- Btu/hr.-ft ²		9.26	11.75	13.10	11.29	9.99	6.43
q -- Btu/hr.		194.5	246.6	274.9	237.0	209.8	134.9
Sub total -- Btu		1,556	1,973	2,200	1,896	1,678	1,079
Total -- Btu		16,916	21,453	23,919	20,615	18,248	11,738

Cycle: GAIN

HEAT LOSS

Duration: 8 hr.

Ti = 65°F

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
(To) Mean Temp.	30.7	21.5	16.4	23.2	28.0	41.2
$\Delta T (T_i - T_o)$	34.3	43.5	48.5	41.8	37.0	23.8
<u>SOUTH GLASS 630 ft.²</u>						
U = 0.58 Btu / hr.-ft ² -°F						/
q" -- Btu/hr.-ft ²	19.89	25.23	28.13	24.24	21.46	13.80
q -- Btu/hr.	12,533	15,895	17,721.9	15,274	13,520	8,697
Sub total -- Btu	100,265	127,159	141,775	122,190	108,158	69,572
<u>OTHER STRUCTURE 100 ft.²</u>						
U = 0.027 Btu/hr.-ft ² -°F						
q" -- Btu/hr.-ft ²	0.926	1.175	1.310	1.130	0.999	0.643
q -- Btu/hr.	92.6	117.5	131.0	113.0	99.9	64.3
Sub total -- Btu	741	940	1,048	903	799	514
<u>ft.²</u>						
U =	Btu/hr.-ft ² -°F					
q" -- Btu/hr.-ft ²						
q -- Btu/hr.						
Sub total -- Btu						
Total -- Btu	101,006	128,099	142,823	123,093	108,957	70,086

Cycle: GAIN

HEAT LOSS

Duration: 8 hr.

$T_i = 65^{\circ}\text{F}$

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
(To) Mean Temp.	30.7	21.5	16.4	23.2	28.0	41.2
$\Delta T \quad (T_i - T_o)$	34.3	43.5	48.5	41.8	37.0	23.8
<u>ENDWALL 612 ft.²</u>						
$U = 0.044 \text{ Btu / hr.} \cdot \text{ft}^2 \cdot ^{\circ}\text{F}$						
$q'' \text{ -- Btu/hr.} \cdot \text{ft}^2$	1.15	1.914	2.134	1.839	1.628	1.047
$q \text{ -- Btu/hr.}$	923.6	1,171.4	1,306.0	1,125.6	996.3	640.9
Sub total -- Btu	7,389	9,371	10,448	9,005	7,970	5,127
<u>WINDOWS 18 ft.²</u>						
$U = 0.56 \text{ Btu/hr.} \cdot \text{ft}^2 \cdot ^{\circ}\text{F}$						
$q'' \text{ -- Btu/hr.} \cdot \text{ft}^2$	19.21	24.36	27.16	23.41	20.72	13.33
$q \text{ -- Btu/hr.}$	345.7	438.5	488.9	421.3	372.9	239.9
Sub total -- Btu	2,766	3,508	3,911	3,371	2,984	1,919
<u>ft.²</u>						
$U = \text{Btu/hr.} \cdot \text{ft}^2 \cdot ^{\circ}\text{F}$						
$q'' \text{ -- Btu/hr.} \cdot \text{ft}^2$						
$q \text{ -- Btu/hr.}$						
Sub total -- Btu						
Total -- Btu	10,155	12,879	14,359	12,376	10,954	7,046

HEAT LOSS

Cycle: GAINDuration: 8 hr. $T_i = 65^\circ\text{F}$

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
(To) <u>GROUND</u> Mean Temp.	30.7 40	21.5 40	16.4 40	23.2 40	28.0 40	41.2 40
ΔT ($T_i - T_o$)	34.3 25	43.5 25	48.5 25	41.8 25	37.0 25	23.8 25
<u>FLOOR</u> 1440 ft. ²						
$U = 0.087$ Btu / hr.-ft ² -°F						
q" -- Btu/hr.-ft ²	2.175	2.175	2.175	2.175	2.175	2.175
q -- Btu/hr.	3,132	3,132	3,132	3,132	3,132	3,132
Sub total -- Btu	25,056	25,056	25,056	25,056	25,056	25,056
<u>BELOW GRADE WALLS</u> 760 ft. ²						
$U = 0.087$ Btu/hr.-ft ² -°F						
q" -- Btu/hr.-ft ²	2.175	2.175	2.175	2.175	2.175	2.175
q -- Btu/hr.	1,653	1,653	1,653	1,653	1,653	1,653
Sub total -- Btu	13,224	13,224	13,224	13,224	13,224	13,224
<u>ft.²</u>						
$U =$ Btu/hr.-ft ² -°F						
q" -- Btu/hr.-ft ²						
q -- Btu/hr.						
Sub total -- Btu						
Total -- Btu	<u>38,280</u>	<u>38,280</u>	<u>38,280</u>	<u>38,280</u>	<u>38,280</u>	<u>38,280</u>

Cycle: Loss

HEAT LOSS

Duration: 16 hr.

Ti = 65°F

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
(To) Mean Temp.	30.7	21.5	16.4	23.2	28.0	41.2
ΔT (Ti - To)	34.3	43.5	48.5	41.8	37.0	23.8
Roof 960 ft. ²						
U = 0.0268 Btu / hr.-ft ² -°F						
q" -- Btu/hr.-ft ²	0.919	1.166	1.2998	1.120	0.992	0.638
q -- Btu/hr.	882.5	1119.2	1247.8	1075.4	951.9	612.3
Sub total -- Btu	14,120	17,907	19,965	17,207	15,231	9,797
ft. ²						
U = Btu/hr.-ft ² -°F						
q" -- Btu/hr.-ft ²						
q -- Btu/hr.						
Sub total -- Btu						
ft. ²						
U = Btu/hr.-ft ² -°F						
q" -- Btu/hr.-ft ²						
q -- Btu/hr.						
Sub total -- Btu						
Total -- Btu						
	14,120	17,907	19,965	17,207	15,231	9,797

Cycle: Loss

HEAT LOSS

Duration: 16 hr.

T_l = 65°F

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
(To) Mean Temp.	30.7	21.5	16.4	23.2	28.0	41.2
ΔT (T _i - T _o)	34.3	43.5	48.5	41.8	37.0	23.8
NORTHWALL 546 ft.²						
U = 0.0308 Btu / hr.-ft ² -°F						
q" -- Btu/hr.-ft ²	1.06	1.34	1.49	1.28	1.14	0.73
q -- Btu/hr.	576.8	731.5	815.6	702.9	622.2	400.2
Sub total -- Btu	9,229	11,704	13,050	11,247	9,956	6,404
WINDOWS 33 ft.²						
U = 0.057 Btu/hr.-ft ² -°F						
q" -- Btu/hr.-ft ²	1.95	2.48	2.76	2.38	2.11	1.36
q -- Btu/hr.	64.5	81.8	91.2	78.6	69.6	44.8
Sub total -- Btu	1,032	1,309	1,459	1,258	1,114	716
Door 21 ft.²						
U = 0.27 Btu/hr.-ft ² -°F						
q" -- Btu/hr.-ft ²	9.26	11.75	13.10	11.29	9.99	6.43
q -- Btu/hr.	194.5	246.6	274.9	237.0	209.8	134.9
Sub total -- Btu	3,112	3,946	4,398	3,792	3,357	2,159
Total -- Btu	13,373	16,960	18,908	16,297	14,426	9,279

Cycle: Loss

HEAT LOSS

Duration: 16 hr.

Ti = 65°F

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
(To) Mean Temp.	30.7	21.5	16.4	23.2	28.0	41.2
ΔT (Ti - To)	34.3	43.5	48.5	41.8	37.0	23.8
SOUTHWALL 380 ft. ²						
U = $\frac{G_{GLASS}}{0.12} \frac{Btu}{hr.-ft^2-^{\circ}F}$						
q" -- Btu/hr.-ft ²	4.12	5.22	5.82	5.02	4.44	2.86
q -- Btu/hr.	1,564.1	19,836	22,116	19,061	16,872	1,085.3
Sub total -- Btu	25,025	31,738	35,386	30,497	26,995	17,364
SOUTHWALL 380 ft. ²						
U = $\frac{R_{ROCK}}{0.11} \frac{Btu}{hr.-ft^2-^{\circ}F}$						
q" -- Btu/hr.-ft ²	3.77	4.79	5.34	4.60	4.07	2.62
q -- Btu/hr.	14,337	18,183	20,273	17,472	1,546.6	994.8
Sub total -- Btu	22,940	29,093	32,437	27,956	24,446	15,917
ft. ²						
U = $\frac{Btu}{hr.-ft^2-^{\circ}F}$						
q" -- Btu/hr.-ft ²						
q -- Btu/hr.						
Sub total -- Btu						
Total -- Btu	43,965	60,831	67,823	58,453	51,741	33,281

Cycle: Loss

HEAT LOSS

Duration: 16 hr.

 $T_i = 65^{\circ}\text{F}$

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
(To) Mean Temp.	30.7	21.5	16.4	23.2	28.0	41.2
$\Delta T (T_i - T_o)$	34.3	43.5	48.5	41.8	37.0	23.8
END WALL 408 ft. ²						
$U = 0.044 \text{ Btu / hr.} \cdot \text{ft}^2 \cdot ^{\circ}\text{F}$						
$q'' \text{ -- Btu/hr.} \cdot \text{ft}^2$	1.51	1.91	2.13	1.84	1.628	1.047
$q \text{ -- Btu/hr.}$	615.7	780.9	870.6	750.4	664.2	427.3
Sub total -- Btu	9852	12,495	13,931	12,006	10,628	6,836
WINDOWS 18 ft. ²						
$U = 0.057 \text{ Btu/hr.} \cdot \text{ft}^2 \cdot ^{\circ}\text{F}$						
$q'' \text{ -- Btu/hr.} \cdot \text{ft}^2$	1.95	2.48	2.76	2.38	2.11	1.36
$q \text{ -- Btu/hr.}$	35.2	44.6	49.8	42.9	37.9	24.4
Sub total -- Btu	563	714	796	686	607	391
ft. ²						
$U = \text{Btu/hr.} \cdot \text{ft}^2 \cdot ^{\circ}\text{F}$						
$q'' \text{ -- Btu/hr.} \cdot \text{ft}^2$						
$q \text{ -- Btu/hr.}$						
Sub total -- Btu						
Total -- Btu	10,415	13,209	14,727	12,692	11,235	7,227

Cycle: Loss

Duration: 16 hr.

Ti = 65°F

HEAT LOSS

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
(To) Ground Mean Temp.	30.7 40	21.5 40	16.4 40	23.2 40	28.0 40	41.2 40
ΔT (Ti - To)	34.3 25	43.5 25	48.5 25	41.8 25	37.0 25	23.8 25
FLOOR 960 ft. ²						
U = 0.0376 Btu / hr.-ft ² -°F						
q" -- Btu/hr.-ft ²	0.94	0.84	0.94	0.94	0.94	0.94
q -- Btu/hr.	902.4	902.4	902.4	902.4	902.4	902.4
Sub total -- Btu	14,438	14,438	14,438	14,438	14,438	14,438
ft. ²						
U = Btu/hr.-ft ² -°F						
q" -- Btu/hr.-ft ²						
q -- Btu/hr.						
Sub total -- Btu						
ft. ²						
U = Btu/hr.-ft ² -°F						
q" -- Btu/hr.-ft ²						
q -- Btu/hr.						
Sub total -- Btu						
Total -- Btu	14,438	14,438	14,438	14,438	14,438	14,438

Heat loss due to infiftration

$$H = 0.018 (T_i - T_o) IL$$

wind - 15 MPH

	ft. of crack	I $\text{ft}^3/\text{hr.ft.}$
windows	477	24
wood sash, weatherstriped		
doors	40	110

$$\begin{aligned} \text{Infiltration rate} &= L(I)_w + L(I)_d \\ &= 11448 + 4400 = 15848 \end{aligned}$$

Heat loss

Nov.	-	H = 9,784.6 (24 hr) = 234,829 Btu/day
Dec.	-	H = 12,408.9 (24 hr) = 297,816 Btu/day
Jan.	-	H = 13,853.3 (24 hr) = 332,047 Btu/day
Feb.	-	H = 11,924.0 (24 hr) = 286,177 Btu/day
Mar.	-	H = 10,554.8 (24 hr) = 253,314 Btu/day
Apr.	-	H = 6,789.3 (24 hr) = 162,943 Btu/day

Thermal Gain

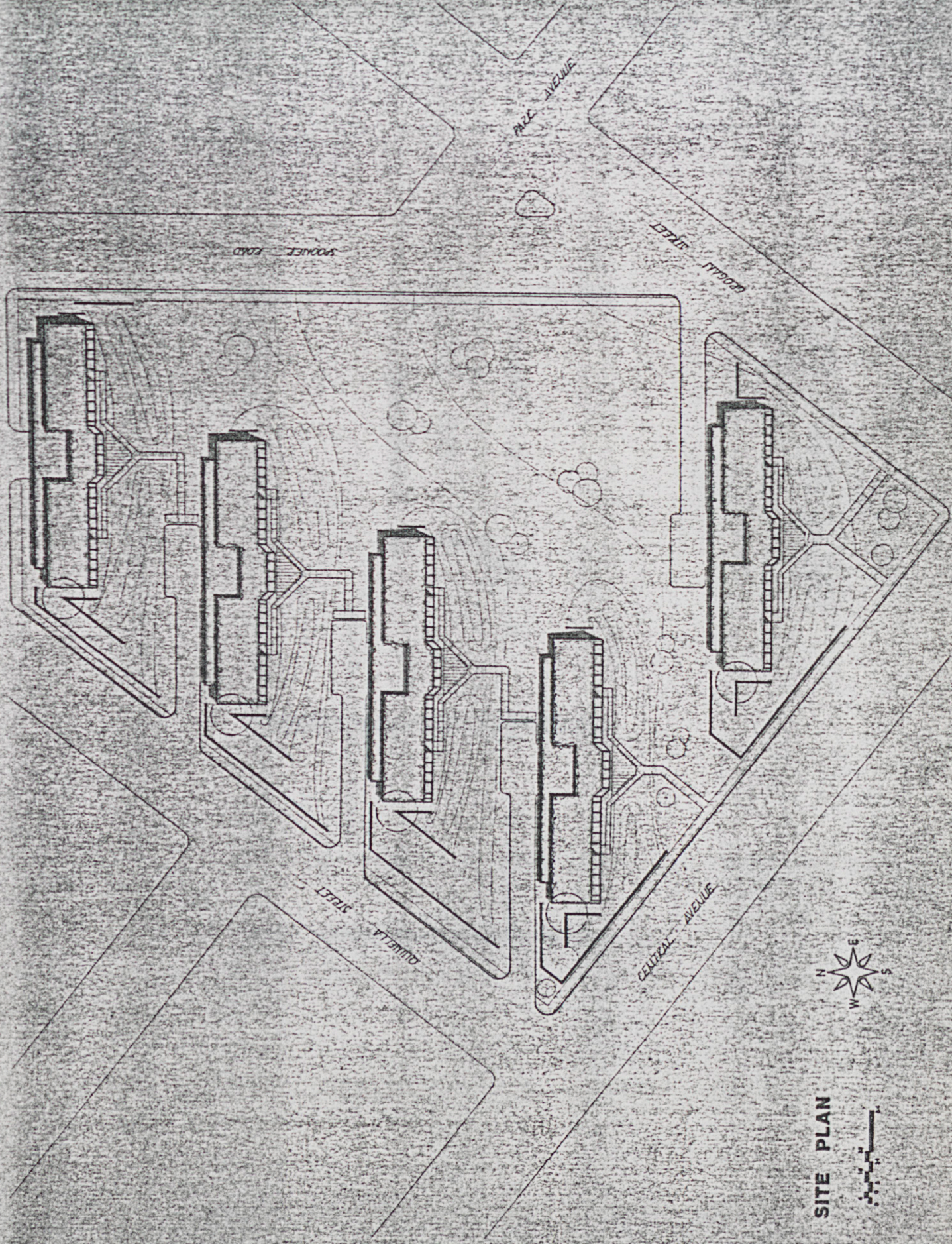
Latitude 44° N.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
South 90° tilt						
Daily Ins. Btu/ft ² *	1,388	1,292	1,420	1,506	1,324	954
Area glass 202.5 ft ²						
sub total	281,070	261,630	287,550	304,965	268,110	193,185
South 55° tilt						
Daily Ins. Btu/ft ² *	1,484	1,341	1,515	1,768	1,831	1,686
Area glass 409.5 ft ²	6					
sub total	607,698	549,140	620,393	723,996	749,795	690,417
total (Btu)	888,768	810,770	907,943	1,028,962	1,017,905	883,602

* THRU DOUBLE GLASS

Thermal Gain

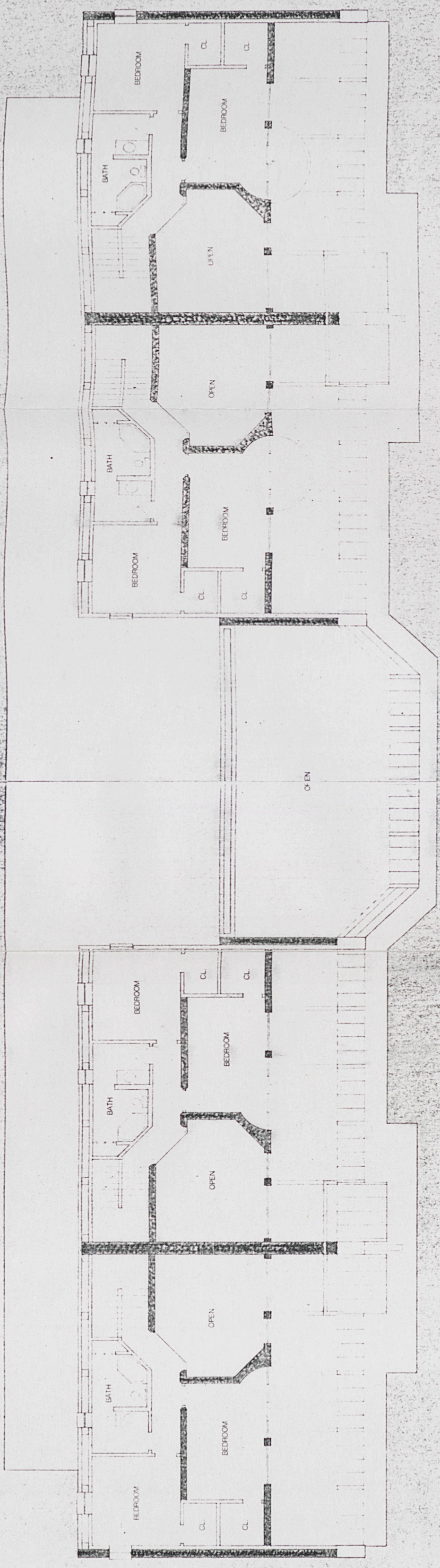
Latitude 46° N.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
South 90° tilt						
Daily Ins. Btu/ft ²	1,579	1,395	1,579	1,857	1,852	1,538
Area glass 202.5ft ²						
sub total	319,747	282,487	319,747	376,042	375,030	311,445
South 55° tilt						
Daily Ins. Btu/ft ²	1,663	1,473	1,663	2,110	2,311	2,311
Area glass 409.5ft ²						
sub total	680,999	603,194	680,999	864,045	946,354	946,354
total (Btu)	1,000,746	885,681	1,000,746	1,240,087	1,321,384	1,257,799

Design Reductions



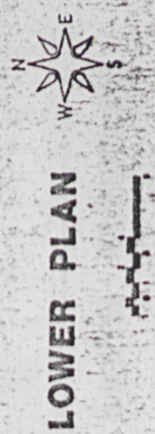
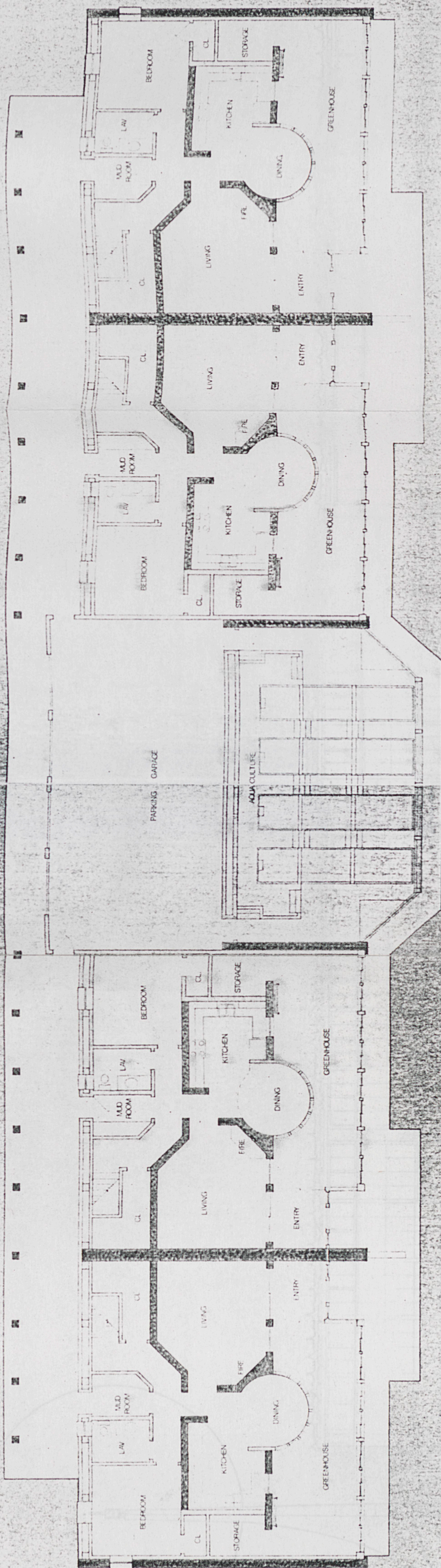
SITE PLAN



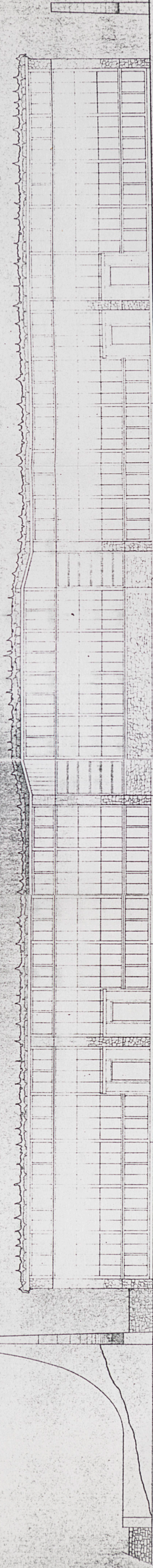
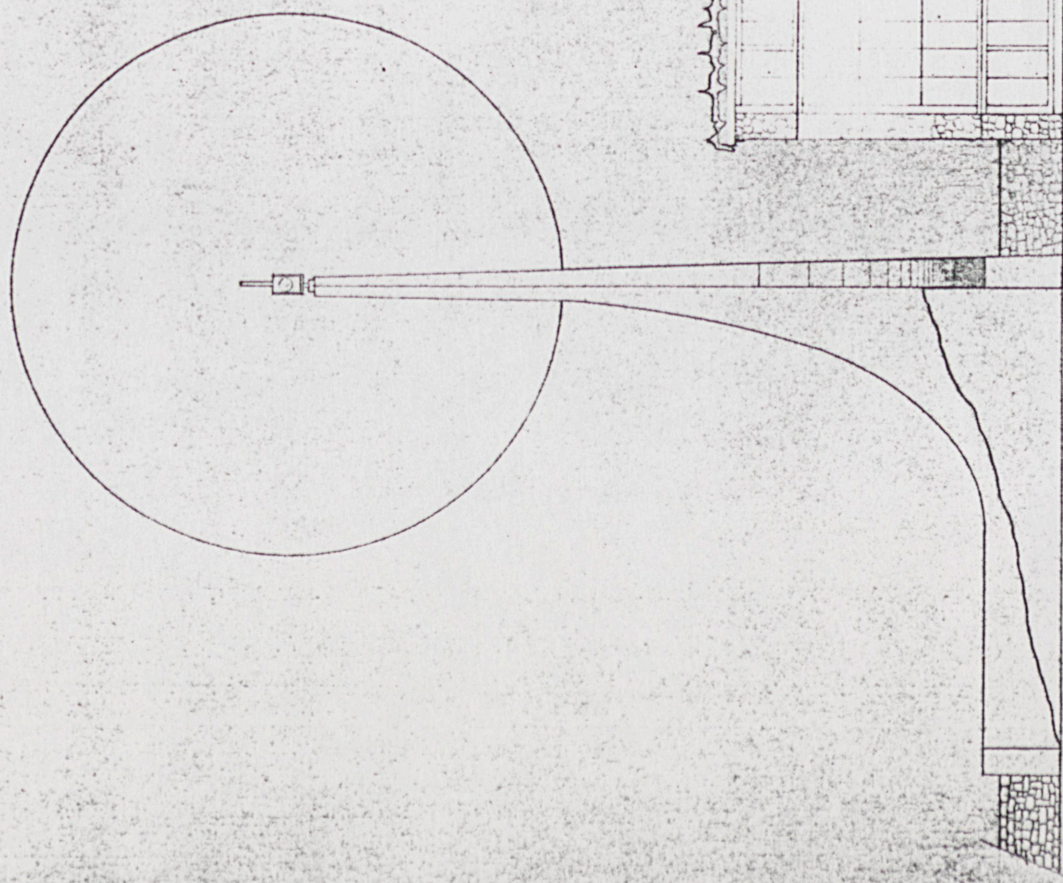


UPPER PLAN

N
W
E
S

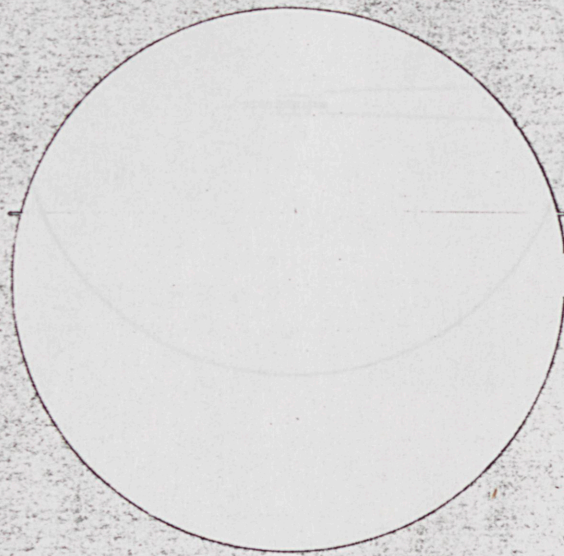


LOWER PLAN

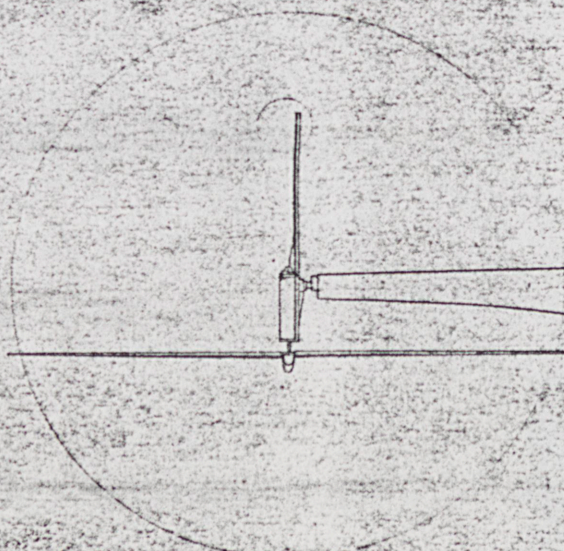


SOUTH ELEVATION



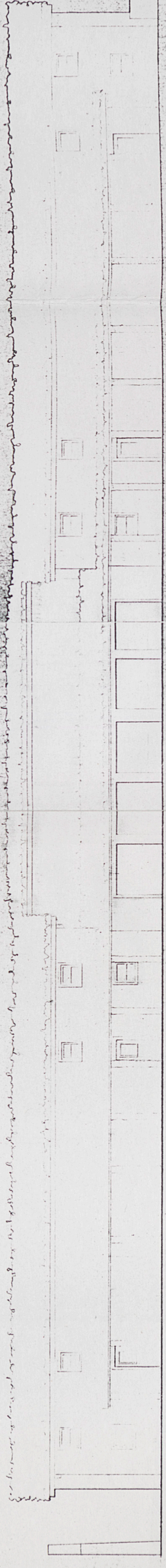
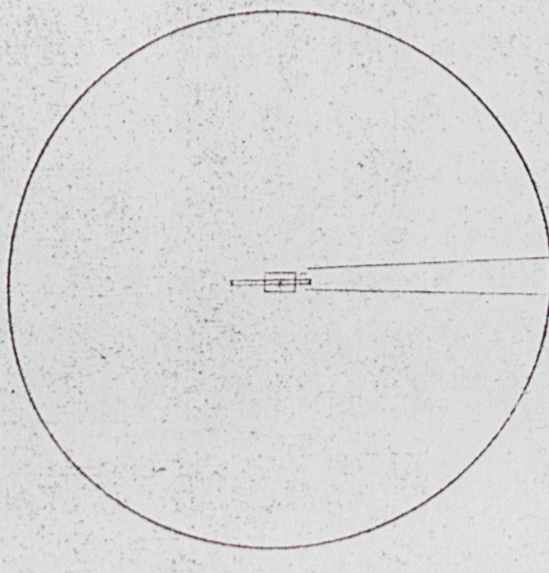


WEST ELEVATION

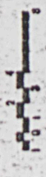


EAST ELEVATION

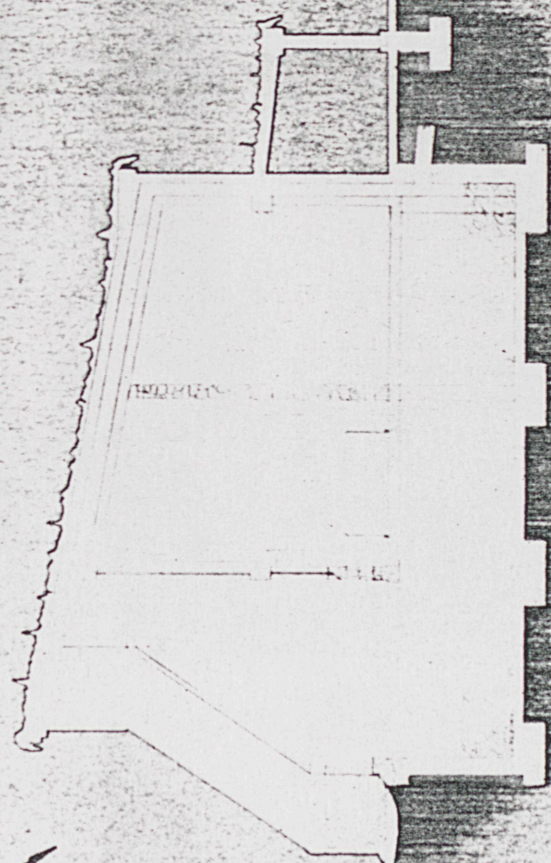
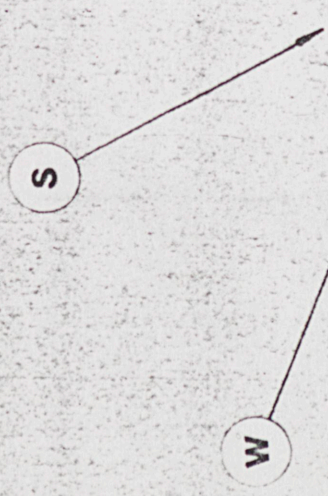
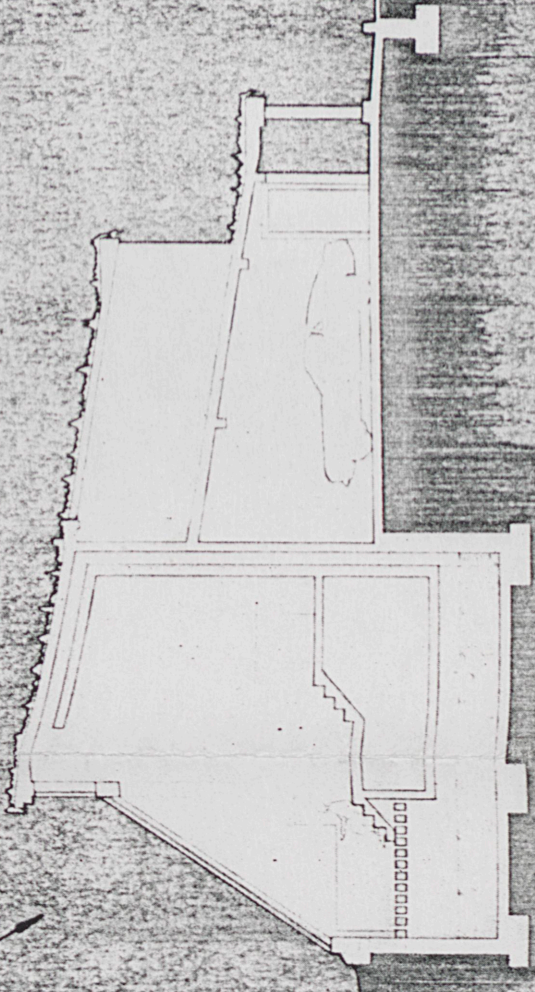
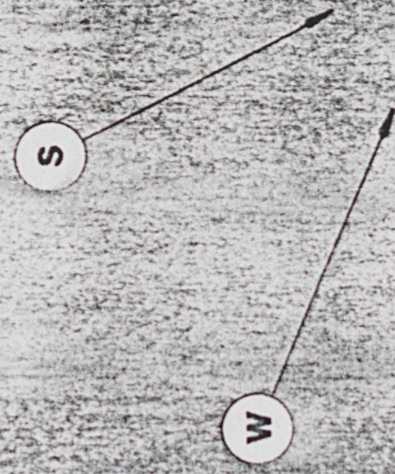




NORTH ELEVATION



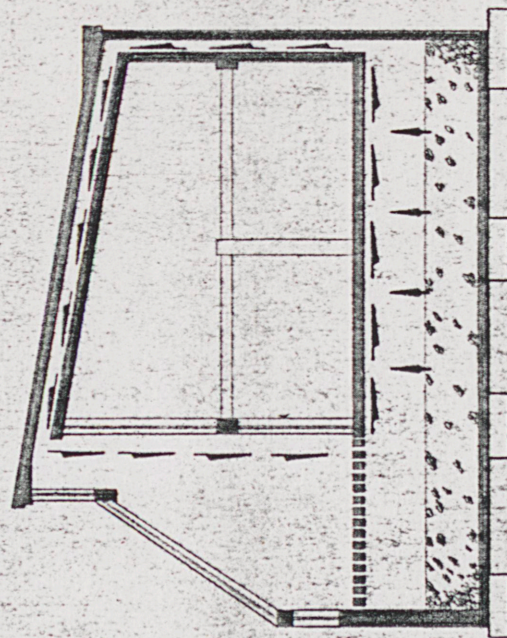
SECTION A-A



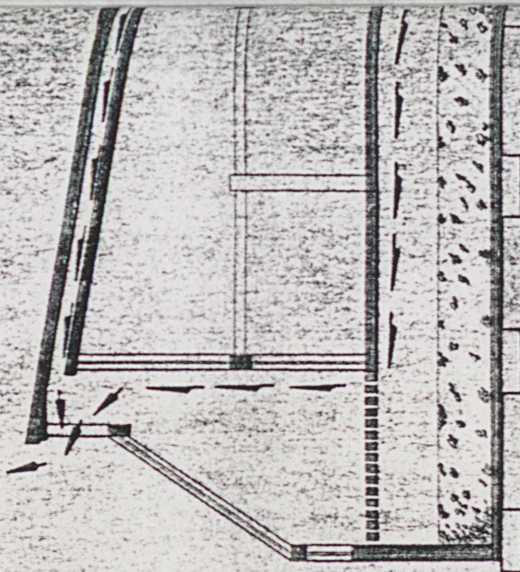
MODES OF TEMPERATURE REGULATION



GAIN CYCLE



LOSS CYCLE



VENT CYCLE

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