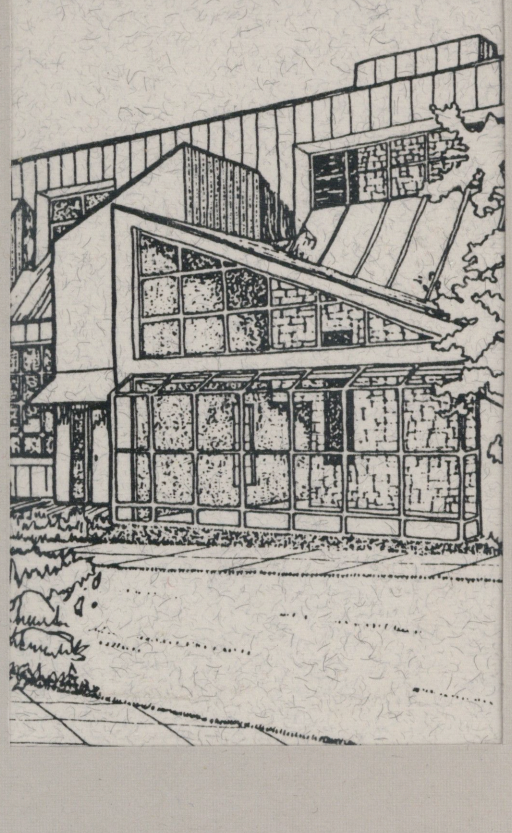
Montana State University Library, Bozeman



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A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

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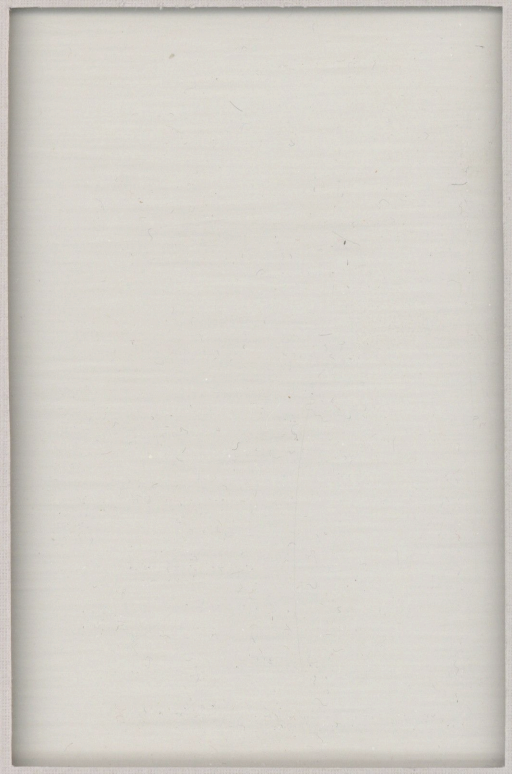

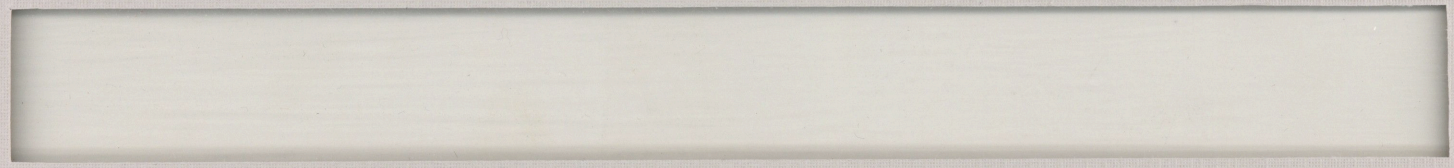

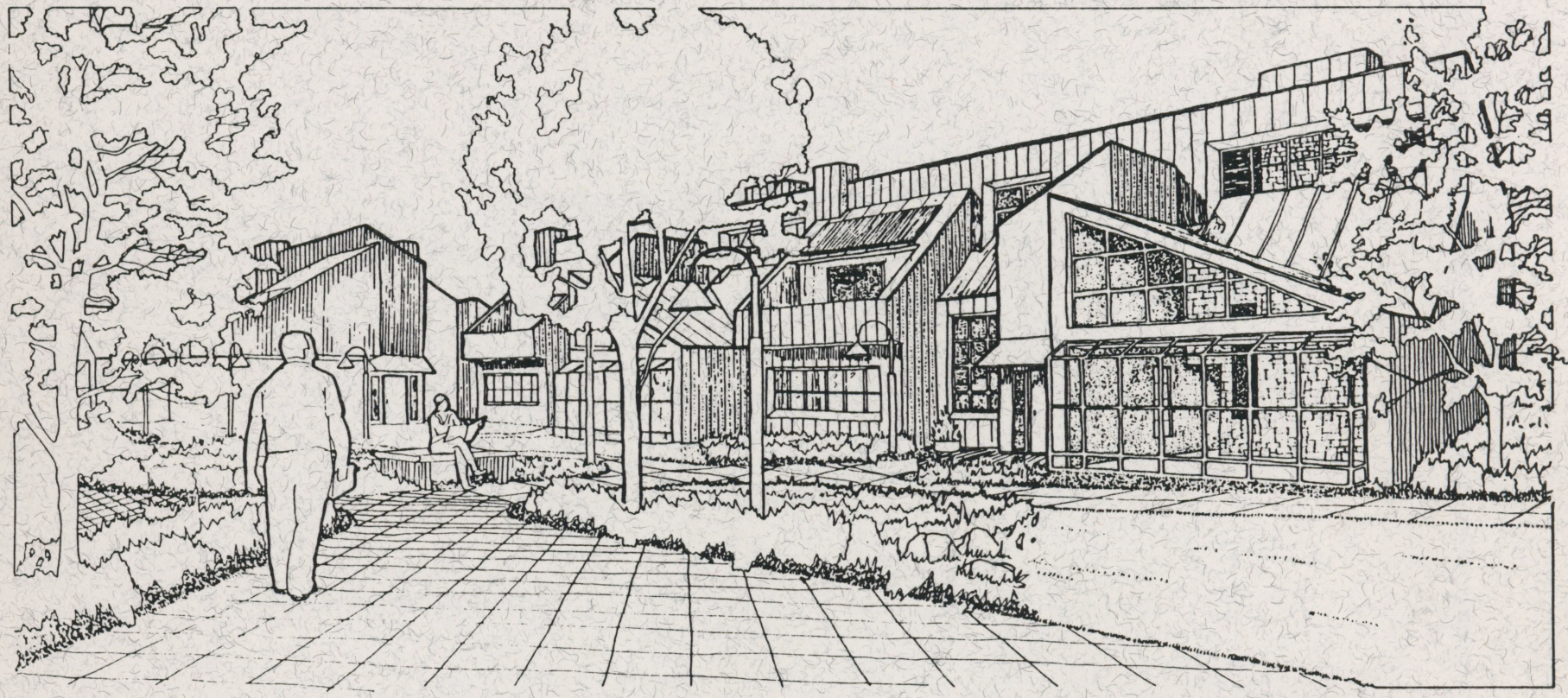

A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

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Montana State University
Bozeman, Montana

Alan Godfrey

Submitted in partial fulfillment of the requirements for the degree of:

Bachelor of Architecture

Advisor: _____
Peter Kommers

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A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

THESIS STATEMENT

The intent of this thesis is to be a case study of energy design integration in single and multi-family housing. Montana State University has intended to build a new faculty housing complex. This project will be located at the site of the old faculty court. This project will be an investigation of how passive and active systems can be integrated in to the design of single and multi-family housing while at the same time enhancing the quality of life. The housing for the faculty will be of a higher quality than traditional student housing.

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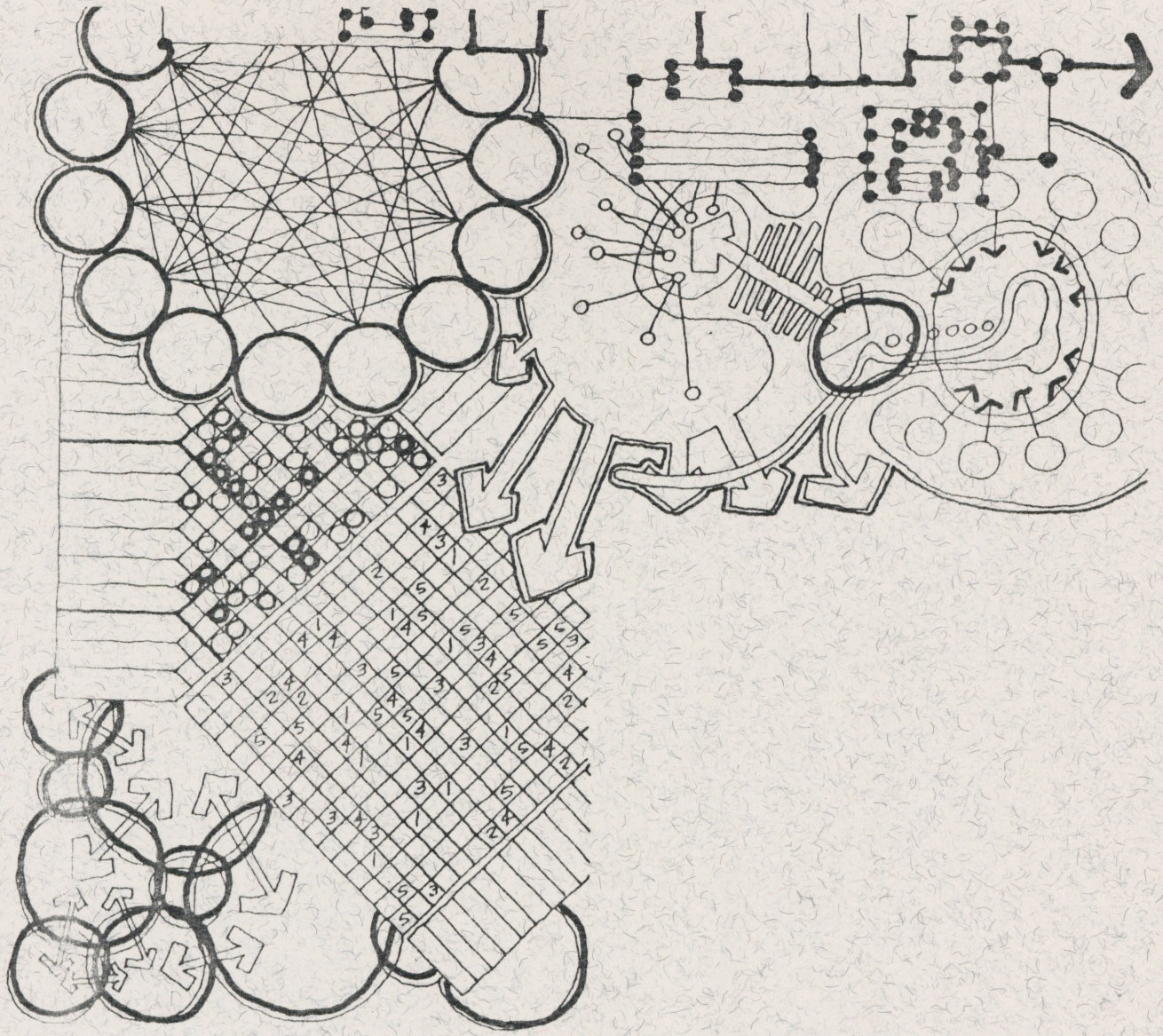
MONTANA STATE UNIVERSITY BOZEMAN, MT.



A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

PROGRAMING

Statement of Purpose

This project is to facilitate the need for adequate faculty housing. The housing is for faculty that are not seeking permanent housing in the area of Montana State University. The project should provide for safe and comfortable accommodations for new incoming faculty, and faculty that will only be here on a short time basis. The project should include convenience and accessibility, and at the same time provide a sense of security and privacy. Because of the type of atmosphere that the university fosters, there will be a strong need for community and social interaction in the faculty housing project. Many times in a project on a university campus the individual needs are ignored for the economies of scale. Individuality will be an important design consideration. This project will be an exercise in urban planning on one hand and a small scale design problem on the other.

QUALITY OF LIFE

What is the quality of life? Could it be the good experiences that occur every day? Quality of life in terms of housing is the intrinsic values that make life more comfortable. The intrinsic values are not always easy to find.

What are the qualities that lend themselves toward good experiences? The one common value that we all look for is a sense of belonging. When we talk about a sense of belonging in housing we are referring to the sense of community. And what must be present to bring forth this sense of community?

The second quality would be a sense of security. We need a safe and secure environment for our children and our selves to grow in.

The third is the ability to care for and protect our children. This important in that we need to feel that our children can grow and mature without fear of harm to the children.

The fourth is livability, which is three part. The first is privacy in the individual dwellings. The second is the need for alternate views for the inhabitant. The third is for cross ventilation, which is important for a healthy environment.

Fifth would be sensitivity to the surrounding context. This includes scale, light, views, and harmony with the community.

The sixth important quality is maintainability of the housing development. The construction of the structures and the building materials used are important in how easy or difficult it will be to service and maintain the property.

Seventh, is the relationship of the automobile to the built environment and to pedestrian traffic. There is a need to reduce noise, and increase safety. This usually means a separation of the vehicle and the pedestrian.

Last but probably most important is maintaining the individual identity of the inhabitants.

There are eight qualities that are important for a healthy environment:

* Belonging - Community
* Security - Safety
* Children
* Livability
* Context
* Maintenance
* Auto - Pedestrian
* Identity - Individual

GOALS

Sense of Identity
individuality.

Sense of Community
belonging.

Sense of Security
safety.

Children's well being
safe and healty place for activitys.

Maintenance
Low maintenance materials.

Quality
higher quality housing,
a standard that faculty are used to.

Livability
privacy, views, ventilation.

Context
sensitivity to surrounding architecture,
and community.

Pedestrian vs Vehicle
separation of pedestrian from vehicular traffic.

Noise
quiet areas are important for
relaxation and study.

PROGRAMMING GOALS

Function

1) Housing designed to fill the needs of the new faculty, at the same time reduce the demand on student housing, with the benefit of increasing recruiting possibilities.

2) Thirty to forty units are needed at this time with the possibility of future expansion.

3) The identity of the individual must be maintained.

4) There should be a combination of private and public social interaction.

5) A sense of place and a strong feeling of security are essential to the well being of the inhabitants.

6) Hierarchy of client goals as stated by the housing director: quiet, secure, comfortable, safe, accessible.

7) Activities are: recreation, relaxation, study, in each of the following catagories, public and private.

8) Parking needs to have good access with out interfering with the activities in the housing development.

9) Security must be inherent in the project, so that a sense of safety and well being is evident. But not pushed to the extent of confinement.

10) Vehicular traffic should not interfere with pedestrian activities, also children activities should not have direct access to traffic areas.

11) Although the vehicle is a part of our every day lives, it should not interfere with the quality of life in the development.

12) Chance and planned encounters will be important for the social contact which reduces the feeling of isolation.

13) Functional efficiency as far as energy and maintenance are concerned are extremely important, and noise will be an important problem also.

14) Parking should be set aside for each unit, and should be separate. There should be parking for both the resident and the visitor. This will reduce conflicts and tension for the motorist.

Form

15) Trees on the site are limited and should be saved if at all possible. The hedge that boarders the site is a important asset, which helps protect the site from visual pollution, and also give a sense of security. Utilities should all be put underground and can be moved to suit the design.

16) The project should consider the environmental impacts of material uses, and most important the energy implications. Also the planting of trees to produce oxigen. This project should try to follow the policies of "green architecture" where possible.

17) The character of the project environmentally should not follow current trends, but exemplify the way we would like the future of housing to be.

18) This project should not only be an enhancement of campus housing but should also consider the Bozeman community as well.

19) The psychological environment of the project should lend it's self as a haven from the stresses of campus activities. ie. noise, parking, lack of privacy, safety, security, and fast pace of campus activities.

20) Promotion of individuality of user should be inherent in that each unit should have user defined attributes.

21) Because the university is mainly a pedestrian atmosphere, most of the emphasis will be given to the pedestrian as primary traffic, and the vehicular traffic as secondary.

22) There should be a strong sense of entry and arrival, and orientation should be simple.

23) The image should be that of a small community that is healthy, safe, stable, and comfortable. This is extremely important due to the transitory nature of faculty housing.

24) The user will expect a higher quality of housing than is normally available on a campus.

25) The public spaces should promote both chance and forced social interaction. While on the other hand private space should be secure but have the features such as light, view, and shelter.

Economy

26) The extent of available funds will be limited by the university and state legislation. Because the land is not an expense and the energy design will be good publicity, it is not expected to be a barrier.

27) Cost effectiveness will be measured on a long term basis. The construction will be of low maintenance and durable materials.

28) The goal for minimizing operating costs of the physical plant will be achieved by the use of good energy design, using both active and passive systems.

29) The initial costs of construction will be high due to the energy designs, but within the life cycle there will be a sizable return.

Time

30) The social and functional organization should be as dynamic as possible without damaging the sense of community.

31) Anticipated change and growth of the project is probable and possible. There should be identification of possible expansion in the overall plan of the project.

Montana State University
Faculty Housing Development
Date of Project: Dec. 1991
Problem Statement

Function

Since emphasis must be placed on pedestrian movement in the faculty housing project and on the campus, the master plan must provide for separation of the pedestrian and vehicular traffic.

Since the housing project needs a strong sense of community there will be a need for entry, procession, and arrival.

Because noise is an important consideration it will be important for zoning of vehicular, pedestrian, public, private, and service areas.

Since the University will be responsible for servicing the housing, there must be strong consideration of serviceability.

Since there is a diversity of the faculty population and lifestyles, there is a strong need for sense of place to foster social interaction.

Form

Since energy and social interaction are important considerations, clustering of the units is desirable.

Since there is need of isolation of the pedestrian from vehicular traffic and the noise of services, there will be need for zoning of opposing activities.

Since the pedestrian is emphasized, short walking distances should be inherent in the over all plan.

Since the site is barren and austere, the site should create green planted areas for the psychological needs of the user.

Since the University represents higher education and enlightenment, the architecture should represent contemporary and progressive design.

Since the views of the mountains are an important attribute, there should be emphasis of the southern exposure.

Because of the diversity and transitory nature of the user, there is a need to develop a highly stimulating environment.

Since the small urban site has several external physical and social responsibilities, the design should respond to these external influences as well as to the needs for functional requirements.

Form

Since the site is relatively featureless the design should provide the appropriate image for the development.

The climate and community attitudes will call for a regional architectural response.

Since the development of this site will serve as a model for future projects, The design must communicate this project is of quality and integrity and will be a leader in the housing market.

Economy

Since the project will be a showcase for residential development, there must be a high level of design and construction quality.

The university seeks a high level of performance for it's investment in services, plant, and equipment and this attitude towards, or emphasis upon, cost effectiveness should be intrinsic to the planning of the housing project.

Because the faculty are used to a high quality of housing, the project must meet the expectations of the faculty, who will be utilizing the housing.

Because housing is important to prospective faculty, there is a great need for quality faculty housing.

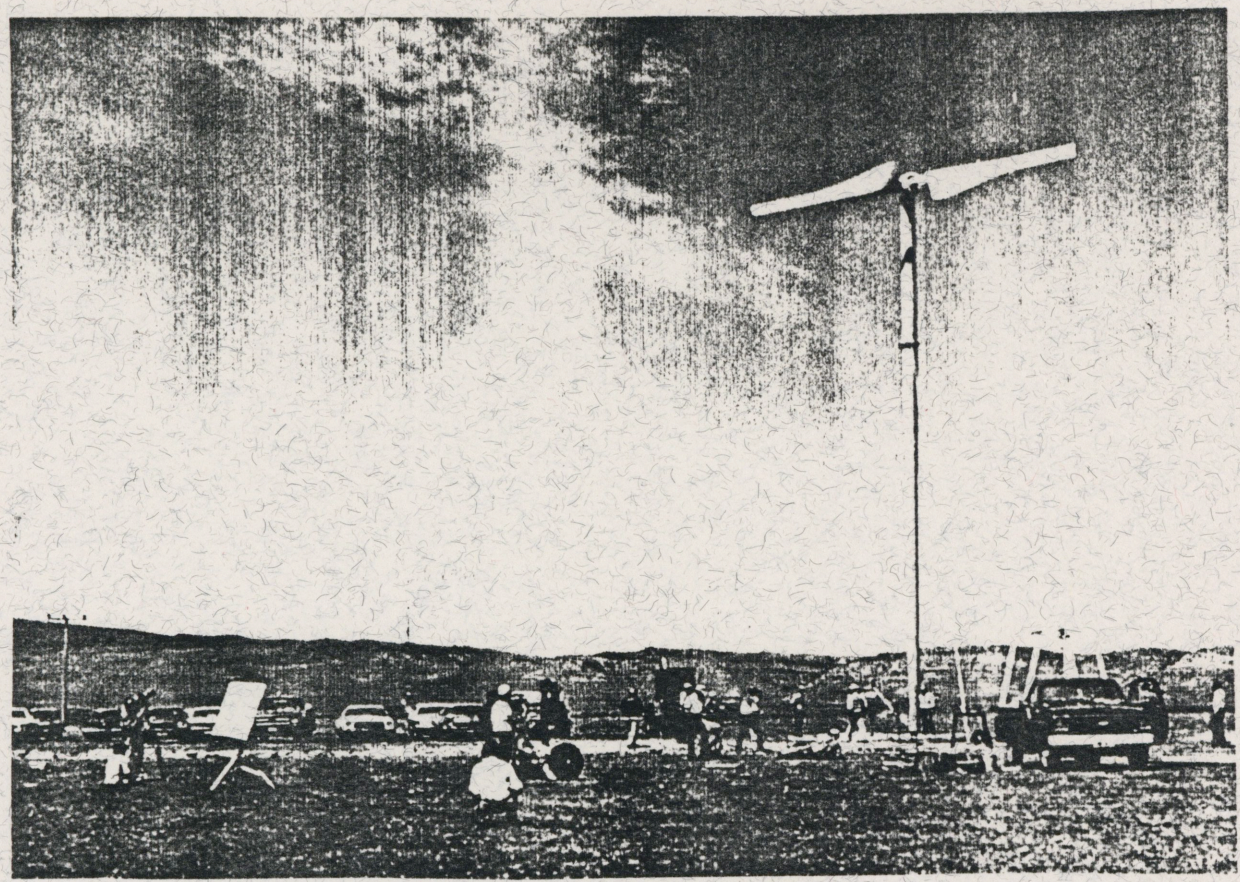
Time

Since the university requirements will grow beyond expected levels, the master plan must allow an open ended framework for expansion.

PROBLEM STATEMENT

FACULTY HOUSING NEEDS

The current need for Montana State campus faculty housing is about 30 three or four bedroom units. In a recent interview with the Director of Family Housing at Montana State University, the needs were for 40-50 three or four bedroom units. The current policy is to reserve 30 of the student family housing units for faculty. By the end of August these units were filled. There is about 45% single units and 65 % family units. Occupancy is restricted to not more than 6 months for faculty and limited to one year for post-doctoral fellows and visiting one year faculty. The faculty in student housing are expected to find off campus housing before the end of the time limit. These limits are imposed due to the extreme shortage of student family housing. The university has a very limited number of three bedroom apartments and nothing larger. The waiting list for these larger units is well over 18 months. The functionality of the current units is at best very poor. Most single faculty prefer the quiet of the towers (Nelson-Story, Peter Koch). As noted by the Director of Family Housing there has been a trend toward larger more stable families. This trend has caused a great need for the three to four bedroom units. It was also mentioned that the current housing has many problems, a few of which are; noise, maintenance, and accessibility. Another of the problems is that faculty are more accustomed to a much better quality of housing than what is currently available. In conclusion the need for quality housing is extremely important to the wellbeing of the university and its faculty.

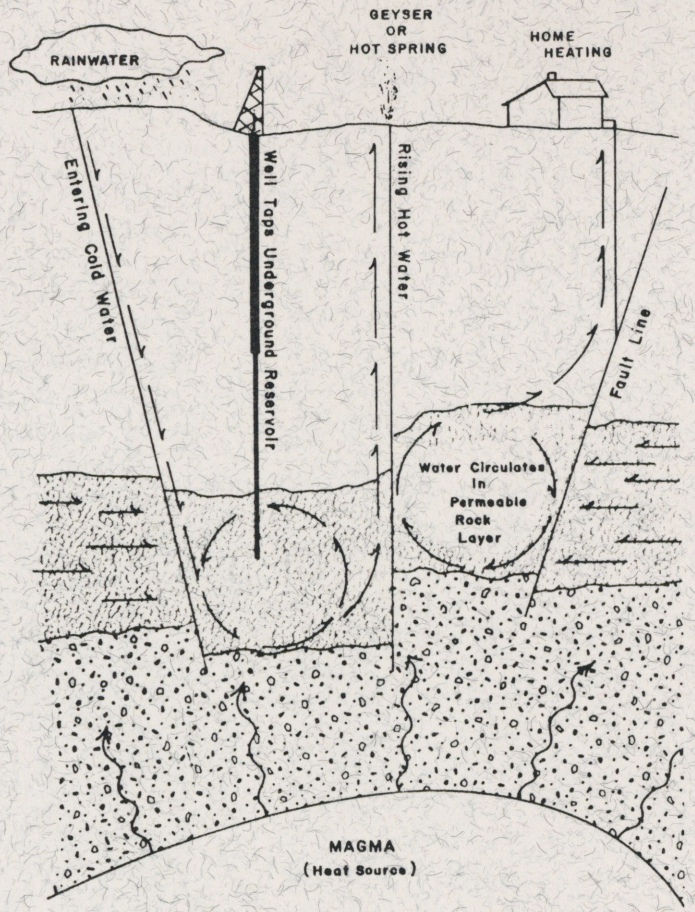


A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

ENERGY SYSTEMS

14



Deep Circulation of Geothermal Water

ENERGY FUTURE

A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

What is our energy future?

This is one of the greatest questions of our time and can not be overstated. The economy and health of the world are dependant on energy. The problem is two part, dwindling fossil fuel supply, and carbon emissions. The answer to the problem is a simple one. Greatly improved energy efficiency in the short run, complemented by renewable energy in the long run.

In 1974 the presidential mandate was to reduce dependance on fossil fuels. To a small degree this has been accomplished, but not by finding alternate sources, but by a more efficient use of energy. We can only use this strategy in the short run. Soon the economics of supply and demand will catch up with us. We have bought ourselves some time with greater energy efficiency, but time is running out.

Instability in the Middle East is situated in an area where the worlds largest oil reserves are located. Iran, Iraq, and Syria are among a few of the countries contributing to the political instability of the Middle East. It would not be difficult for a group to take over the worlds oil supplies and bring the economies of the world to it's knees. This was evident when Iraq took over the small country of Kuwait. World fuel prices sky rocketed over 100%. If they had gone further and moved into Saudi Arabia, the world's economy would have come crashing down. This dependance on non renewable energy is a very serious problem.

The problem of carbon emissions from fossil fuels are causing acid rain, and adding to the green house effect. The green house effect has caused slight changes in the earth's temperatures and turned green lands into deserts. The final solution is not better energy efficiency, or new exploration, but reduced dependance on fossil fuel energy sources.

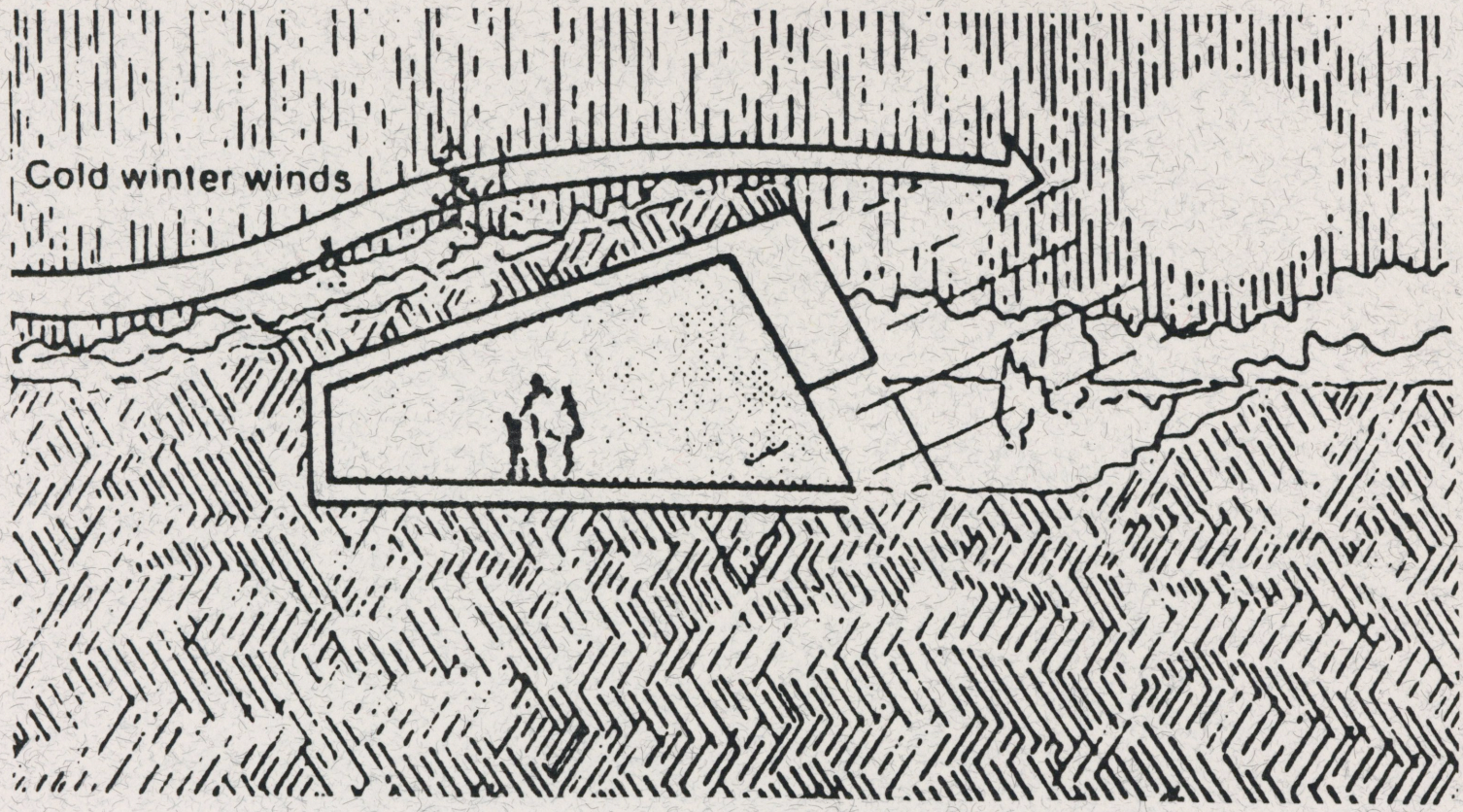
It is obvious that we must rely more on renewable energy. Then what about nuclear energy? Nuclear energy only supplies about 5 percent of the worlds energy. Future development is impaired by the politics of health and safety concerns. Currently the French have come up with a way to deal with nuclear waste that is safe but expensive. They have drilled wells that are over five miles deep into the earth to store radioactive waste.

With the new technological developments of the last decade we can build safe and more reliable nuclear power plants. Because of the accident at Cheranoble and Three Mile Island the world has great missgivings concerning nuclear power.

If not oil or nuclear power then how about coal? Some governments subsidize coal mining while at the same time spending large sums of money to clean up the pollution in the air. Energy policy is often contradictory. Fossil fuels are the main source of the air pollution now choking rural areas and cites. Many American cites still do not comply with air quality standards laid down more than a decade ago. In the U.S. Congress, acid rain bills have languished for several years, due to opposition from those in the coal industry.

The most pressing global problem is that of global warming caused by the build up of "green house" gasses, the most important of which is carbon dioxide. Some six to eight billion tons of carbon are added to the atmosphere each year by the combustion of fossil fuels. Fossil fuel fired power plants alone now produce one quarter of the worlds carbon emissions.

It has become evident that as architects we have a grave responsibility to design more energy efficient construction. We must lead the world towards a more stable energy future.



EARTH SHELTERED

A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

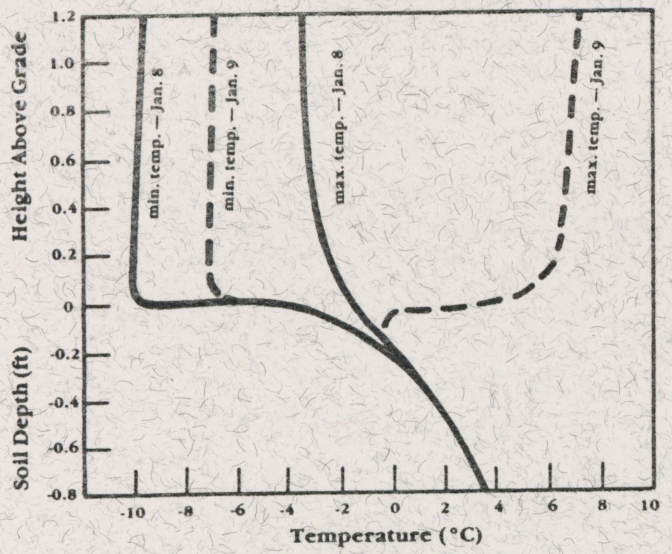


FIGURE 1
Daily Temperature Fluctuation

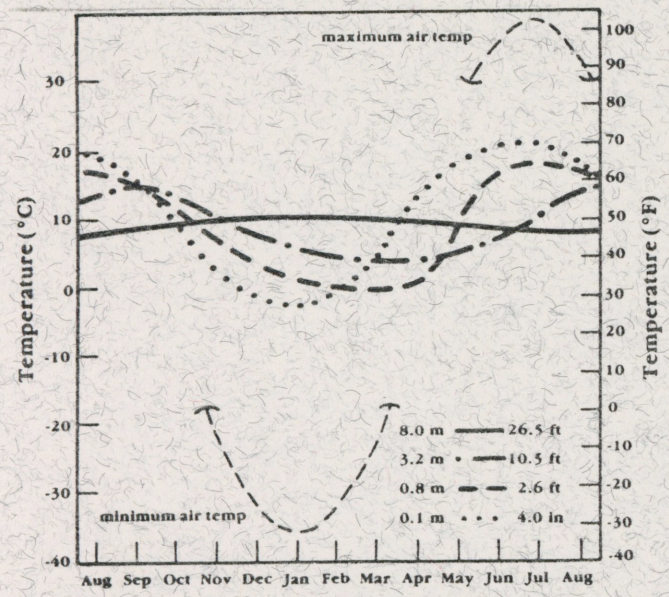


FIGURE 2
Annual Temperature Fluctuation

EARTH SHELTERED HOUSING

Earth sheltered housing incorporates the earth in it's design to give it thermal protection. Earth sheltered housing has many advantages as long as the occupant and designer understand the limitations.

Myths

There are many myths about earth sheltered housing. Some say the earth is a good insulator. This is not so. The earth is a poor insulator. Three feet of earth has an equivalent resistivity (R value) as 3/4" thick polyurethane or 1 1/2" of fiberglass batt. The 3 foot thick blanket of earth over a 1,600 square foot home has a dry weight of over 800 tons. This will present significant structural problems. The Earth does work well as a heat sink or temperature moderator. This heat sink creates a thermal lag which keeps outdoor temperatures from influencing indoor temperatures as quickly. A goal of earth sheltered housing is to store energy in the mass of the earth to reduce temperature fluctuations in the home.

The last myth of earth sheltered housing is that conventional waterproofing is adequate. In fact conventional water proofing is only damp proofing and only stops the capillary draw of moisture, and is not good enough to stop water penetration or bridge cracks. Earth shelter is by no means the only design option. While earth sheltering is a good means to reduce the temperature fluctuations it will not make for an energy efficient home.

Types of earth sheltered homes

The three most common designs of earth sheltered homes is elevational, atrium, and penetrational. These represent the basic design patterns and many derivatives can be made from these plans.

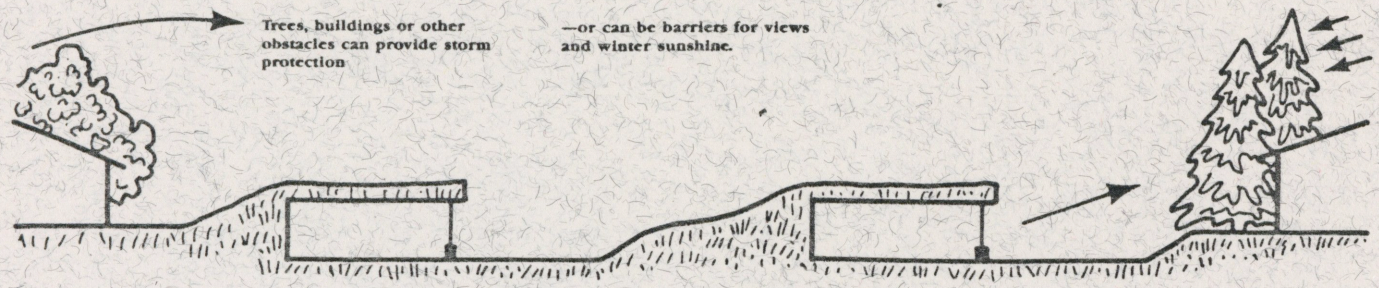
Construction materials

Because of extreme loads and pressure on the earth sheltered structure, conventional materials can not be used effectively. With earth on top or bermed concrete, steel or heavy timbers are required. These special construction techniques increase the initial cost considerably.

Insulation

Although the earth is an good heat sink the structure still needs adequate insulation. The most common is extruded polystyrene because of it's resistance to moisture and compression. Insulation for subgrade use should have:

- High compression strength (20 to 30 psi)
- High resistance to water absorption
- High resistance to the chemical properties of the soil and water
- High R value, or resistance to heat transfer
- Good dimensional and R value stability
- Tongue and groove edge configuration
- Low cost, current availability and easy handling



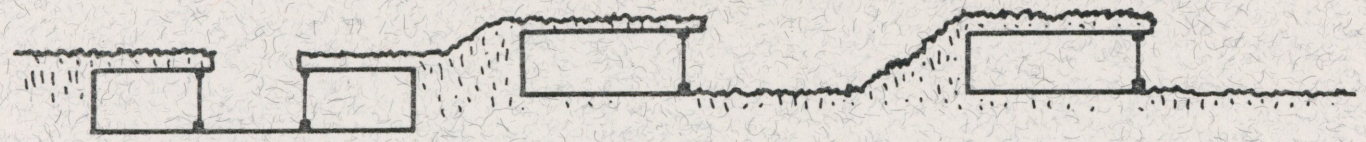
Obstacles on nearby property—either a benefit or a hindrance.

Waterproofing

Good drainage and waterproofing is critical to prevent a wet environment. There is a significant difference between waterproofing and damp proofing. Only waterproofing should be considered for earth sheltered homes. Materials used for waterproofing must be capable of bridging structural cracks, seal themselves, and withstand wide temperature changes.

Summary

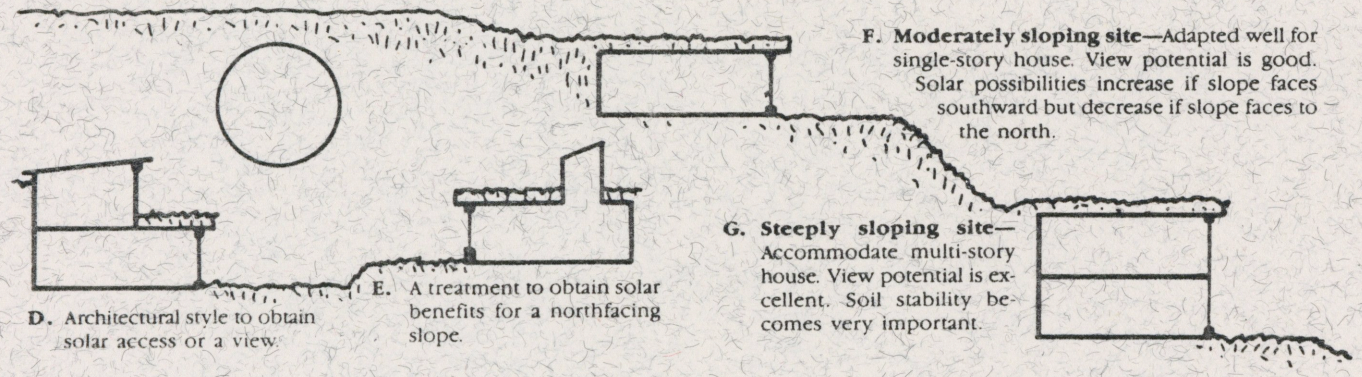
Earth sheltered housing can be an energy efficient housing option. The construction materials and building techniques are different from conventional light framing homes. Most lending institutions will not lend out money for construction without proof of an architect or engineer and contractor.



A. Recessed styling—Site requires exceptionally good drainage. Private view is created within atrium. Passive solar capability is limited by size of atrium. Good protection from noise and storms. Shrubs and trees can prevent wind turbulence in atrium.

B. Semirecessed styling—Low profile allows solar access and natural view to be easily blocked by nearby construction or trees. Private view can provide wind protection.

C. Elevational styling—More space is required for berming. Drainage problems are reduced. Well adapted for sites with shallow bedrock or high water table. Opportunities for solar access and view are improved.



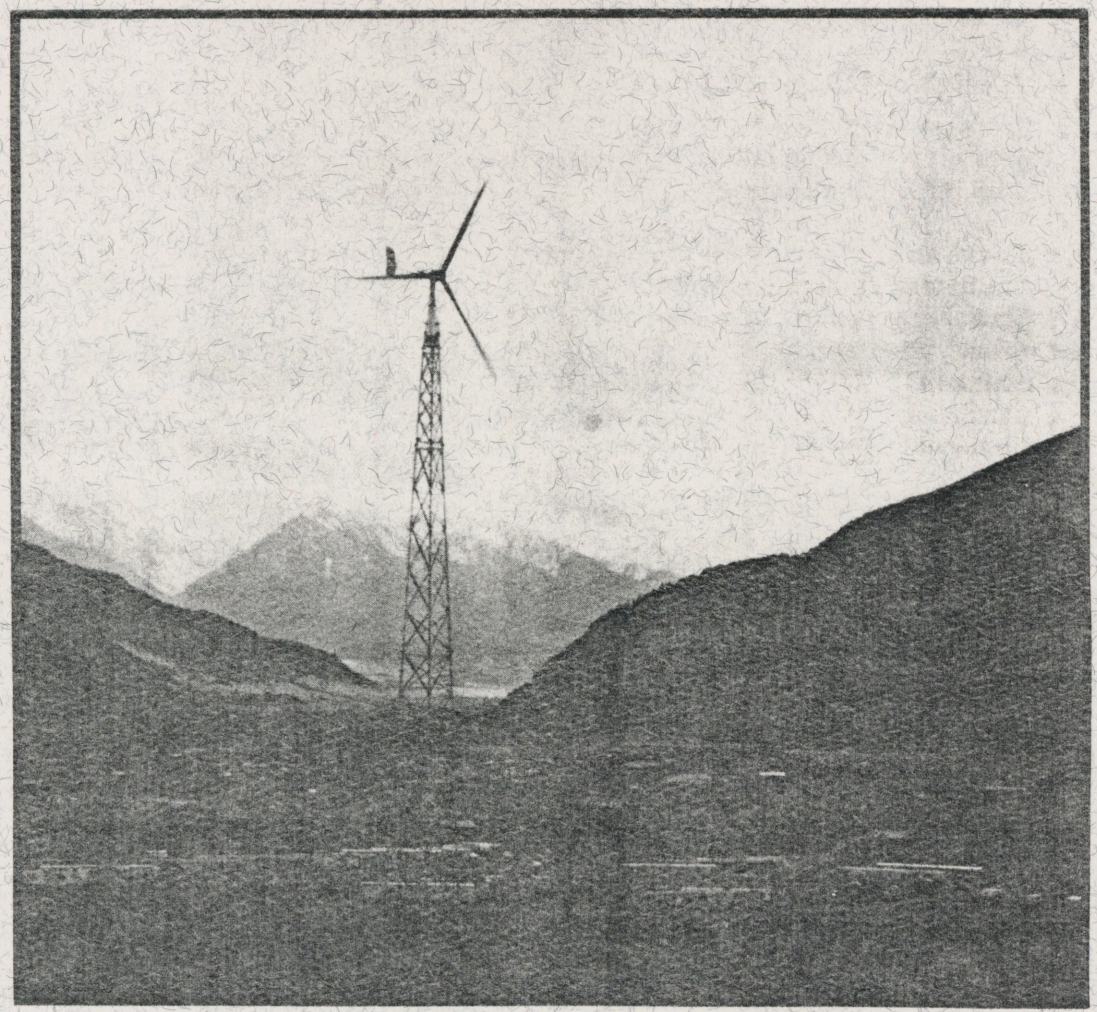
D. Architectural style to obtain solar access or a view.

E. A treatment to obtain solar benefits for a northfacing slope.

F. Moderately sloping site—Adapted well for single-story house. View potential is good. Solar possibilities increase if slope faces southward but decrease if slope faces to the north.

G. Steeply sloping site—Accommodate multi-story house. View potential is excellent. Soil stability becomes very important.

Some architectural styles of earth-sheltered houses that relate to site characteristics.

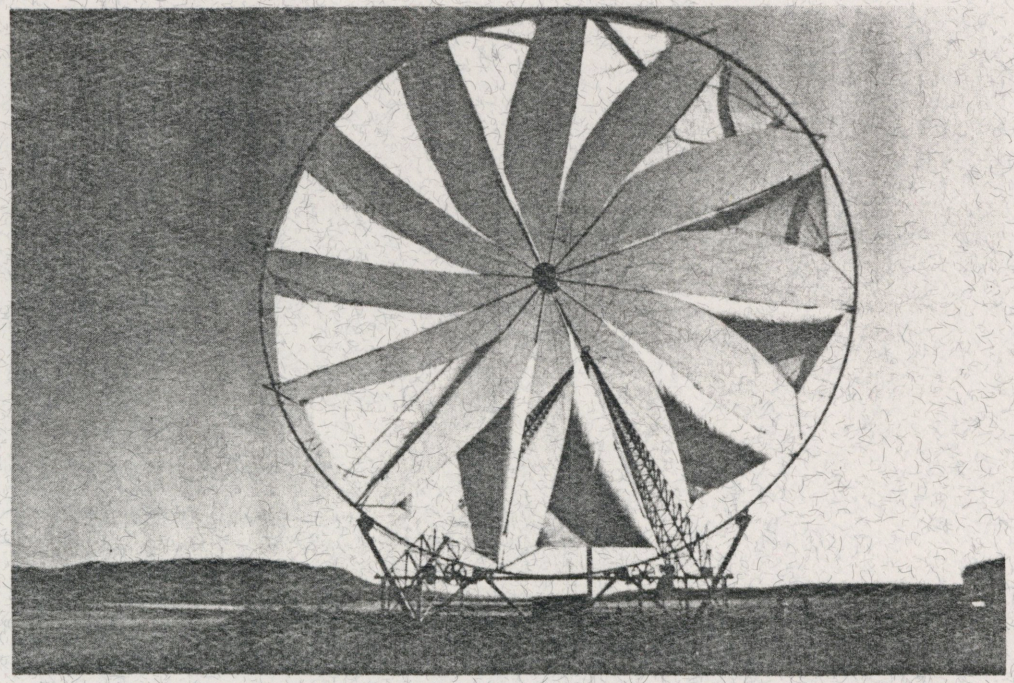


WIND POWER

A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

Wind Power Systems



Montana has some of the best wind energy sites in the country. And some Montanans already harvest power from the wind - power to pump water for their homes; their livestock and there crops; power to heat and light their homes, businesses, farms, and ranches; and power to sell to utility companies. The following information will discuss some of the factors involved in wind power.

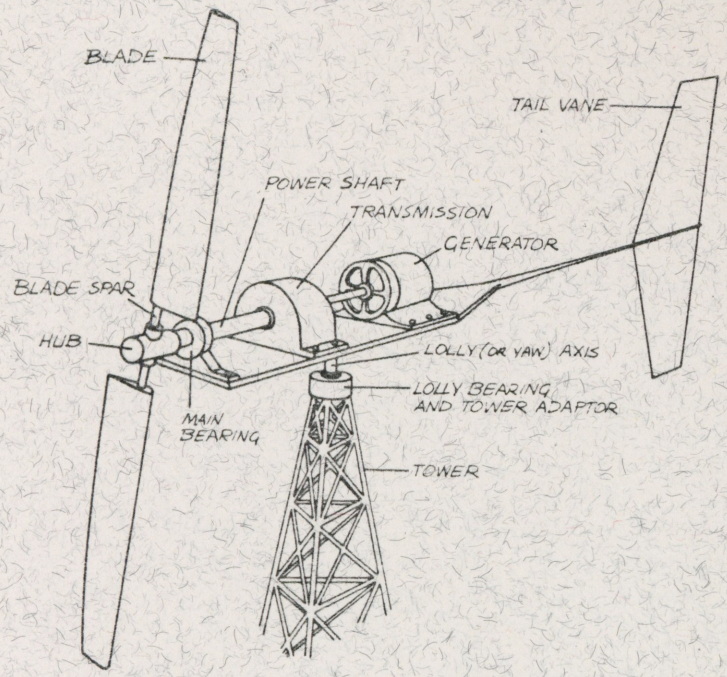
Some of the considerations are important to the success and economic return of your wind machine. Selecting your dealer is the critical step in buying a wind machine. Make sure the dealer has the knowledge and training to install, repair and maintain the machine himself. Don't get involved in a deal where you'll be sending the machine back to the factory all the time because they will have you over the barrel with long distance phone calls and paying for freight.

Also climbing the tower to make repairs is not for everyone. Some towers can be lowered for repairs and maintenance.

In 1978 the Federal Public Utility Regulatory Policy Act (PURPA), which requires power companies to buy electricity generated by independent producers, blew life into the wind farming movement.

A 25 percent federal business investment tax credit coupled with Montana's 35 percent commercial investment tax credit has attracted private firms to wind farming.

Many wind generators don't even start turning until the wind is blowing eight or nine miles per hour. The general rule of thumb is that you need an annual average wind speed of 10 mph to generate electricity, although sail wing and water pumping models work at lower wind speeds.

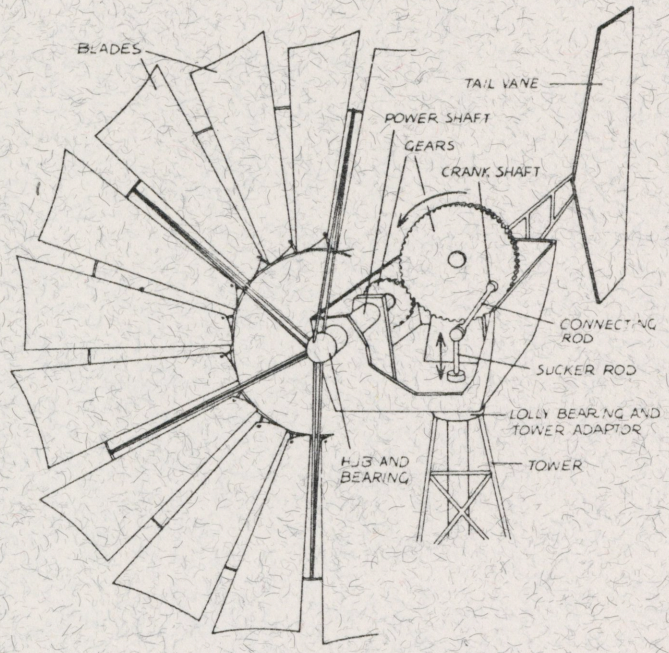


An electricity producing wind generator

Since the power available to your wind generator increases with the cube of the wind speed, a small difference in wind speed can make or break your wind project. The increase from 10 to 12 mph is only a 20 percent increase in wind speed, but it creates an 80 percent increase in power production.

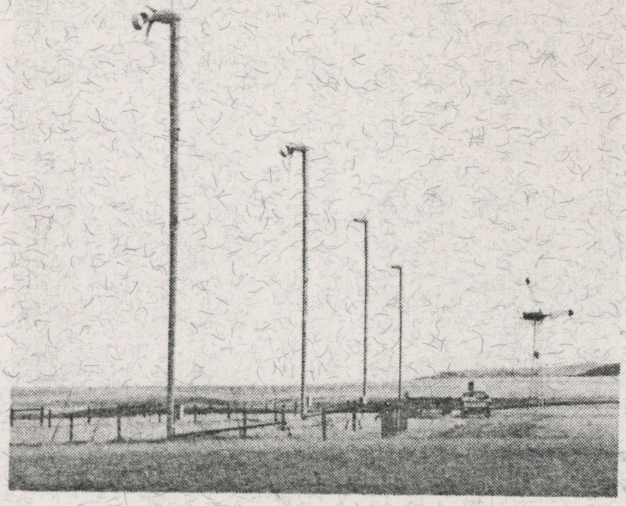
Like any other farming, wind farming has its risks. Generally, fewer than five years worth of data are available on wind turbans, especially the giant utility sized machines. They are still relatively expensive because most of them are still not mass produced.

Research going on today should help mitigate the negative impacts of wind turbans and bring down the costs associated with wind power. Extensive research programs are being carried out by wind machine manufactures and by the federal government with its Rocky Flats Wind System Testing Program in Colorado. The state of Montana encourages research and development with grants and loans through the Renewable Energy and Conservation Program administered by The Department of Natural Resources and Conservation.

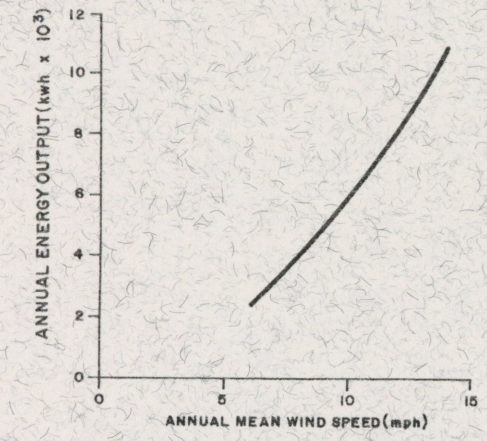


A water pumping windmill.

WIND POWER



The Livingston Wind Farm.



ENERGY COSTS AND
ANNUAL ENERGY OUTPUTS

The economics of wind generators is a delicate one. The machines are expensive and there is no escaping the fact. But with new technology the price is coming down. On the other hand the fuel for these machines are free, and the wind turbines will be producing energy for many decades to come.

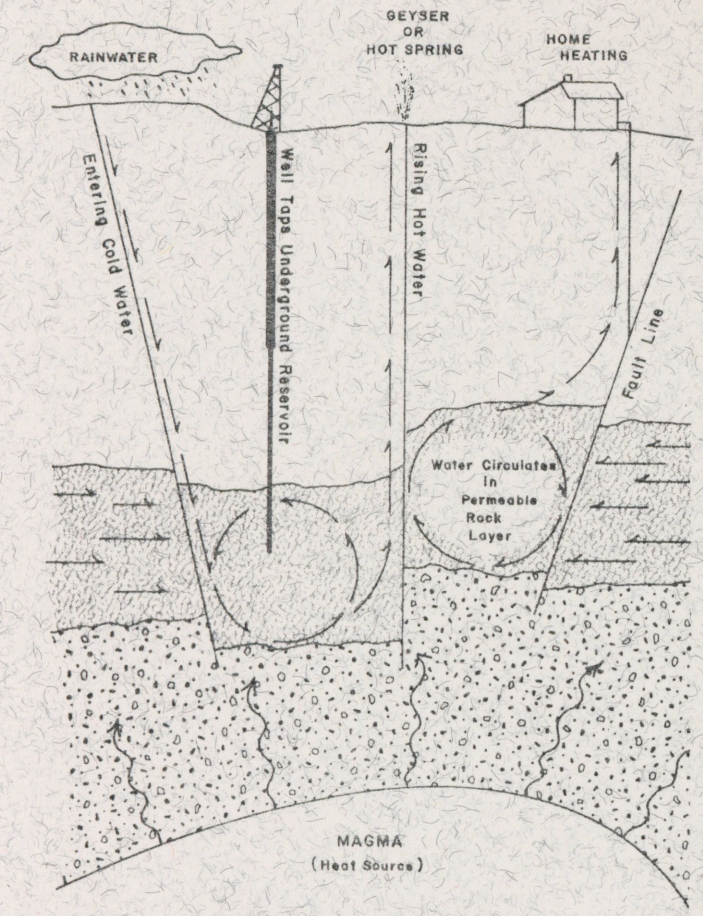


GEOTHERMAL ENERGY

A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

Geothermal Energy



Deep Circulation of Geothermal Water

To many Montanans, winter brings with it not only icy temperatures, but also high heating bills. We can use the geothermal energy by using the heated thermal water and piping it through our home. So how might geothermal energy fit into your life? Would you like to sit back and let mother nature provide you with free heat energy? Unfortunately, it's not that easy.

Here are four major factors to be considered before you undertake a geothermal heating project:

1) Finding a geothermal resource and establishing ownership.
2) Piping geothermal fluid to your home or business.
3) Using the proper heating equipment.
4) Disposing properly of the spent geothermal fluid.

Several thousand miles beneath Montana, the earth's core is surrounded by molten rock (called magma) with temperatures approaching 6,000 degrees. We are protected from these extreme temperatures by insulating soil and rock between the earth's crust and the magma. Even Montana's ground water, hundreds of thousands of feet below us, remains a cool 45 to 50 degrees F year round. However, in certain parts of Montana, there are deep cracks, or fault lines, in the earth. Groundwater that finds its way into these fault lines circulates much deeper than most water, and comes into contact with much warmer areas of the earth's interior.

If this warmed groundwater encounters another fault line, it may move upwards to the earth's surface, where it emerges as a hot spring.

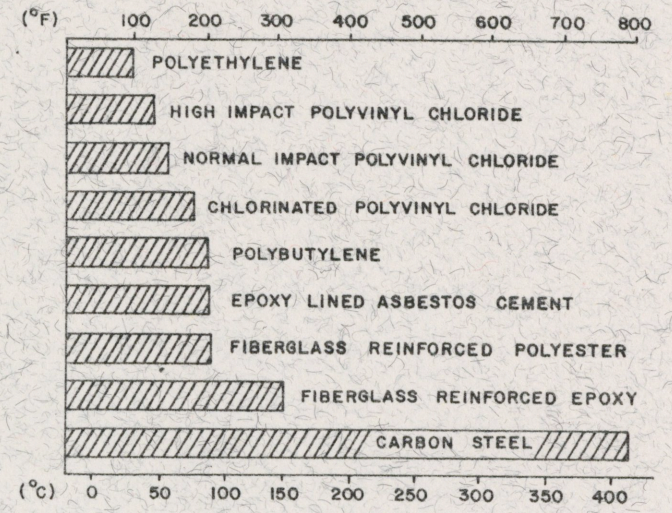
Well drillers occasionally hit hot water by accident, as happened several times in eastern Montana oil fields. More often geologists assist in determining where geothermal wells should be drilled. Many of the techniques used in discovering oil and gas are used to find geothermal deposits: seismic sounding, gravity measurements, resistivity, and test drilling have all been used.

Flow rates for Montana's geothermal resources vary from a few gallons per minute to almost 2,000 gallons per minute of artisan hot water that flows from a geothermal well near Bozeman. Temperatures range from 45 degrees up to 180 degrees F. One of the hottest wells near Poplar, has a temperature that exceeds 240 degrees F.

There is not an unlimited supply of geothermal or cold ground water. The state of Montana has developed a water rights allocation system to track what water is being used, and to determine if sufficient water is available for additional development. Before you start drilling a geothermal well you must obtain a water rights permit from the Montana Department of Natural Resources and Conservation.

Before you can use your geothermal resource for heating, you must pipe the hot water from the well or spring to your home or business. Various types of plastic, adapted to specific temperature ranges, are used. Among the materials used are polyethylene, polybutylene, PVC, and CPVC. For extremely hot water (over 200 degrees F.), carbon steel piping is used.

Water quality can also affect the type of piping used for geothermal systems. These contaminates can cause corrosion or sedimentation in geothermal piping. To prevent this a device called a "heat exchanger" is sometimes used. This device exchanges the heat and prevents the sediments and chemicals from damaging the heating system of the building.



Temperature Ranges for Piping Materials

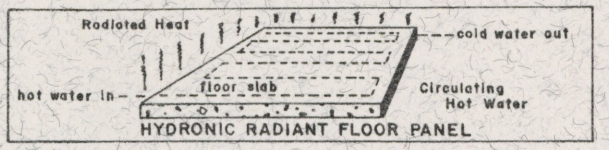
Several things need to be considering when installing a geothermal system. The first is the insulation on the piping to prevent heat loss during transportation. The next is the cost of the piping used. This is the most expensive part of the system.

The temperature of the source can be as low as 85 degrees and still be an effective heating system. Radiant heating systems are probably the best type of delivery device for geothermal energy. The forced air that circulates through heat exchangers is the next type of system that can be used with geothermal energy.

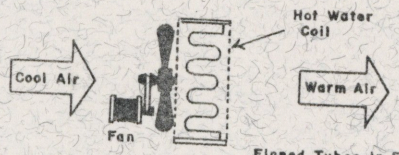
With water temperatures of 85 to 105 should be used in radiant slabs. Temperatures of 105 or better can be used with forced air. If the temperature exceeds 140 degrees, finned tubes can be placed along the walls. Finally if the water temperature reaches 160 degrees the old style cast iron radiators can be used. The efficiency of each type of heating system can be compared by the temperature range required for each type of system. The lower the water temperature required for the system the more efficient the system.

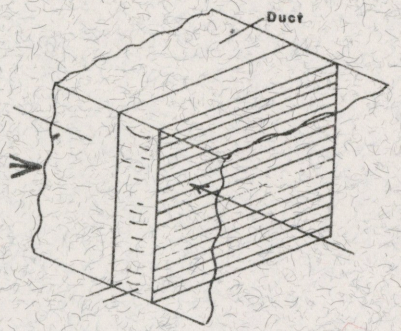
The flow rate required for heating a building varies with the temperature of the water. When the source is hotter then less flow is required. For example a home requiring 14 gallons per minute of 85 degrees would be equal to 2 gallons of water at 140 degrees.

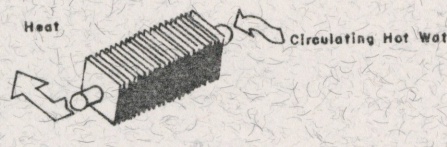
No matter what type of heating system used it is always important to use good conservation tactics. Careful energy calculations are also important to the success of each heating system.

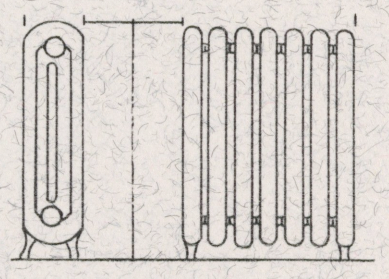


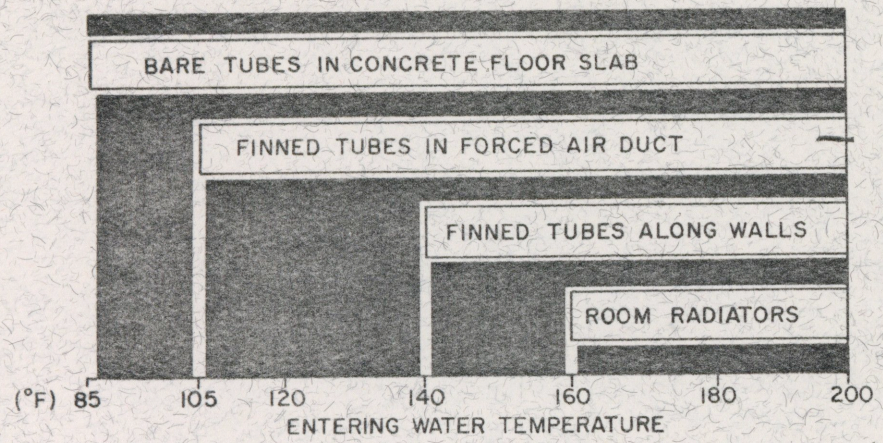
HYDRONIC RADIANT FLOOR PANEL





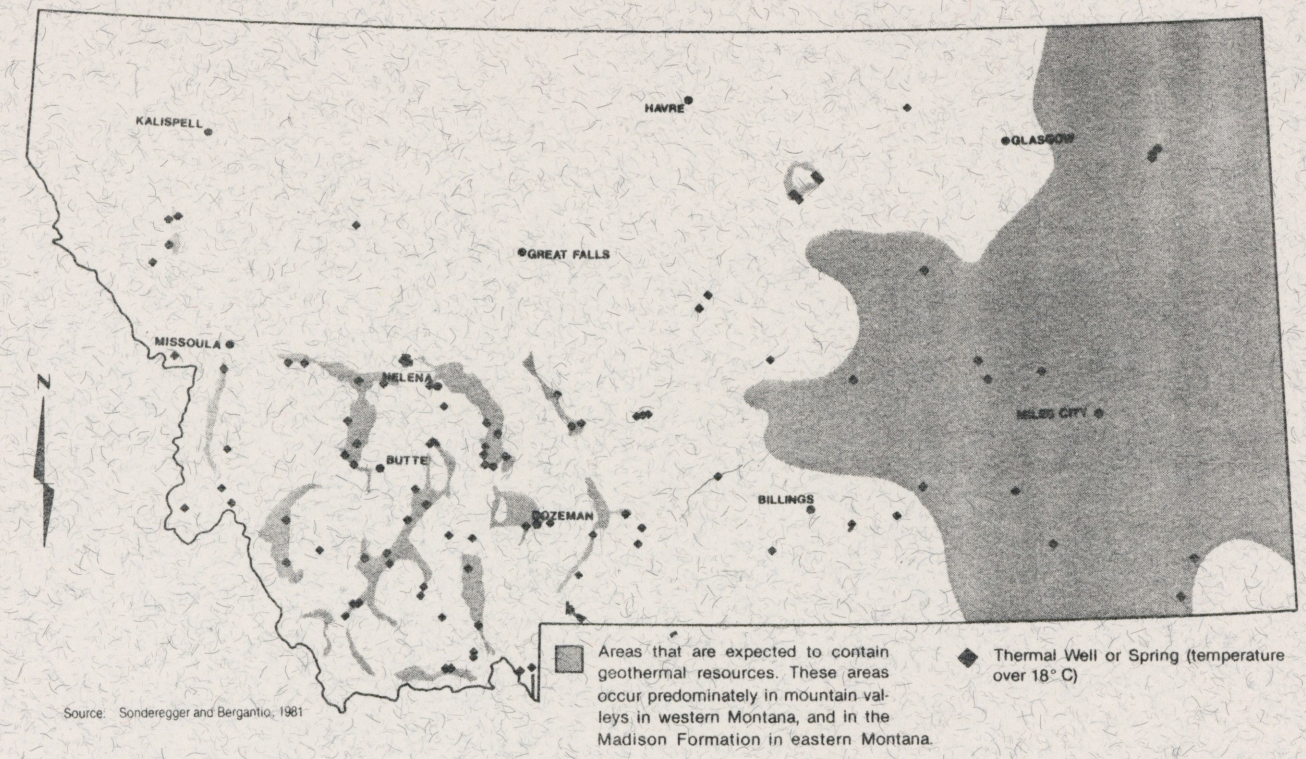






Finally you are faced with the problem of waste disposal of the used water. This water often has very high levels of minerals and an elevated temperature. This type of waste could pollute the pristine streams of Montana. There are thee options for waste disposal. The first is surface discharge. The second choice is discharge to an artificial impoundment. The last is reinjection into an aquifer. The method used will depend greatly on the environmental impact, and a permit must be obtained from the state of Montana.

Even though there are many heating systems using geothermal energy, the state has just touched the tip of the iceberg. The use of geothermal heat energy can be a very economical solution to the energy problem.



GEOTHERMAL RESOURCES OF MONTANA

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GEOTHERMAL ENERGY

32

BIOMASS

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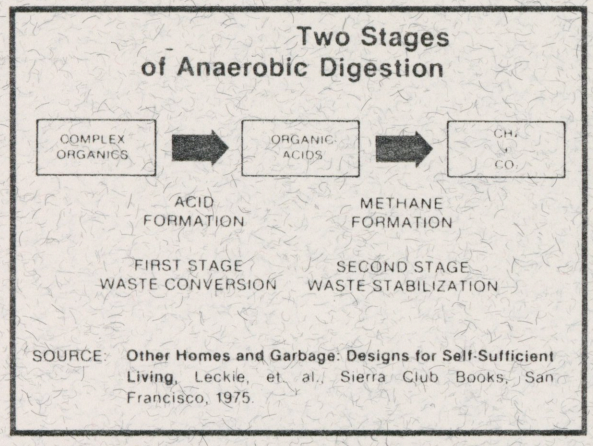
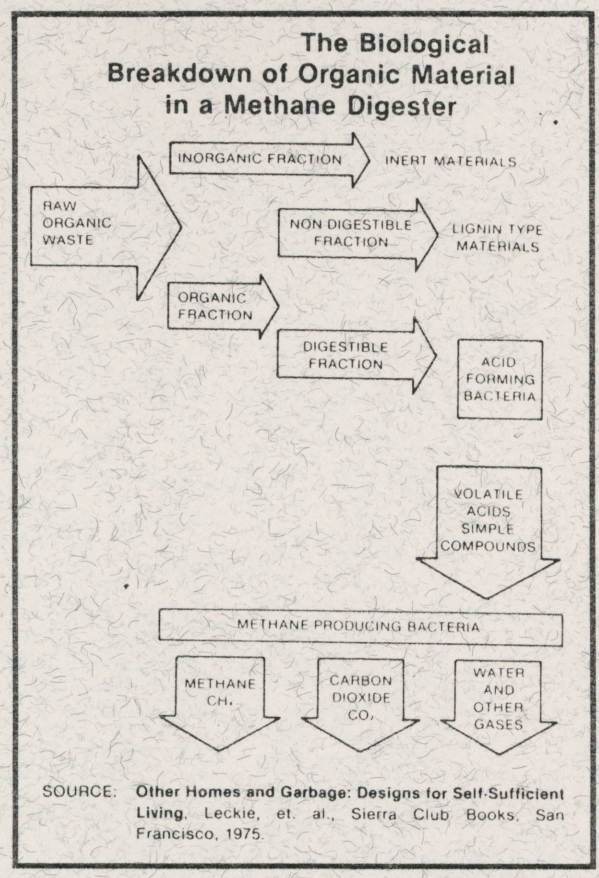
BIOMASS ENERGY SYSTEMS

Biomass energy systems are the use of animal or plant for the production of energy. Wastes: - animal manures, food scraps, harvest waste, human sewage, wood and wood wastes, are a relatively untapped resource. Produced from these wastes are methane gas, alcohol, and heat from combustion. Today many large cities are using biomass systems including, Baltimore, and Oklahoma City. There are three areas in biomass systems which are: the conversions of wastes into bio-gas through anaerobic digestion, potential use of wood wastes and the effective use of wood stoves, and the conversion of wastes in to alcohol fuels.



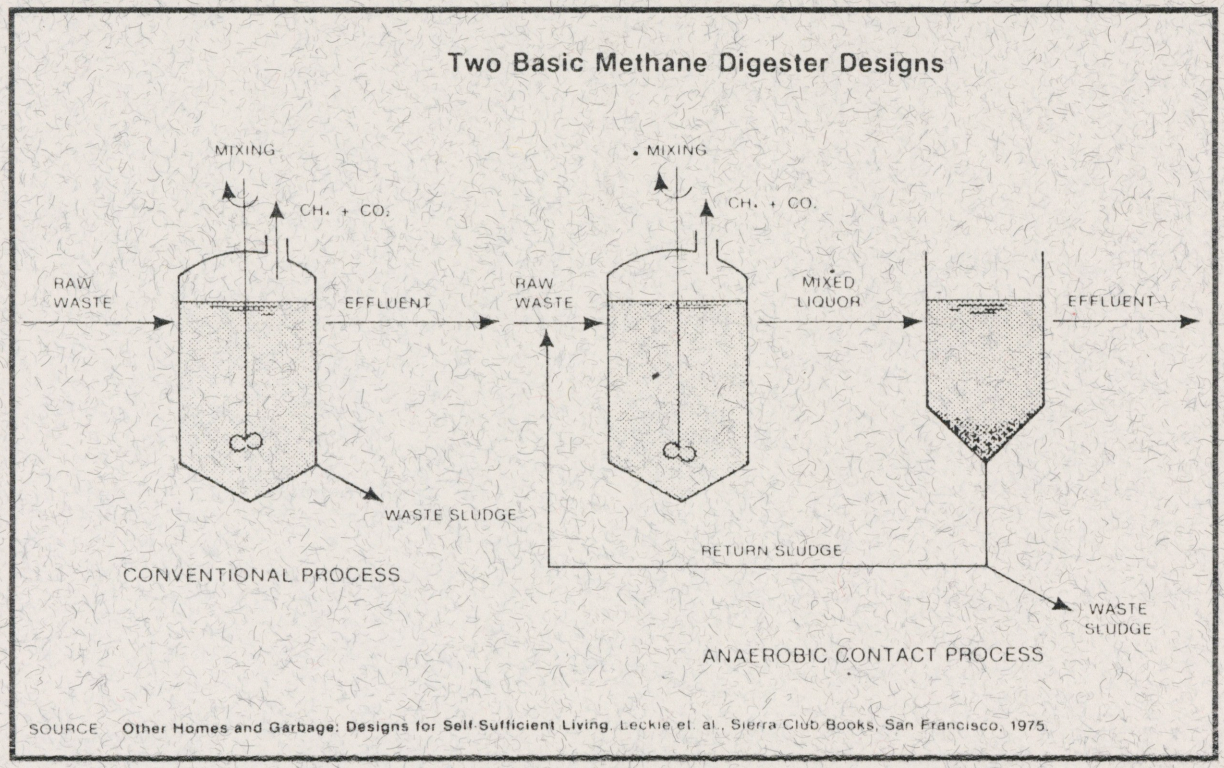


Anaerobic digestion is a process by which bio-gas is produced through the decaying of organic material in the absence of oxygen. Bio-gas contains methane, a combustible gas with a heat valve of about 995 Btu/cubic foot (natural gas contains 1030 Btu/cubic foot at sea level). Also an odorless

by-product of anaerobic digestion is nitrogen fertilizer and soil conditioner.

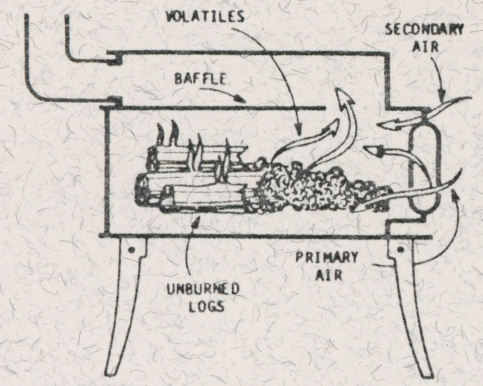
Bio-gas production is suitable to large scale production: city sewage plants, feed lots and food processing plants. Production of these gases from a single household is hardly worth the expense and effort.This is particularly true in the colder climates, because of the heat required to maintain production during colder periods. It is possible to have economical production of methane from a neighborhood sized plant. A single house does not have enough waste to be economical

In anaerobic digestion, organic waste is mixed with large populations of microorganisms in the absence of oxygen. Under these conditions bacteria grow which are capable of converting the organic material to carbon dioxide (CO_2) and methane gas (CH_4). The anaerobic process is a two stage process. The first stage, organic materials are converted to organic fatty acids, brought about by the use of acid forming bacteria. Then in the second stage a special group of methane producing bacteria called methane formers convert the acid to gas. Because these bacteria are anaerobic any small amount of oxygen can be harmful to the bacteria.



SOURCE Other Homes and Garbage: Designs for Self-Sufficient Living, Leckie et. al., Sierra Club Books, San Francisco, 1975.

Typical Scandanavian Woodburning Stove



Most Scandinavian stoves use baffles to encourage a slow, even burn from the front of the logs to the rear. This cigar-like burning pattern prevents the whole fuel load from burning at once and eliminates the need for a thermostat.

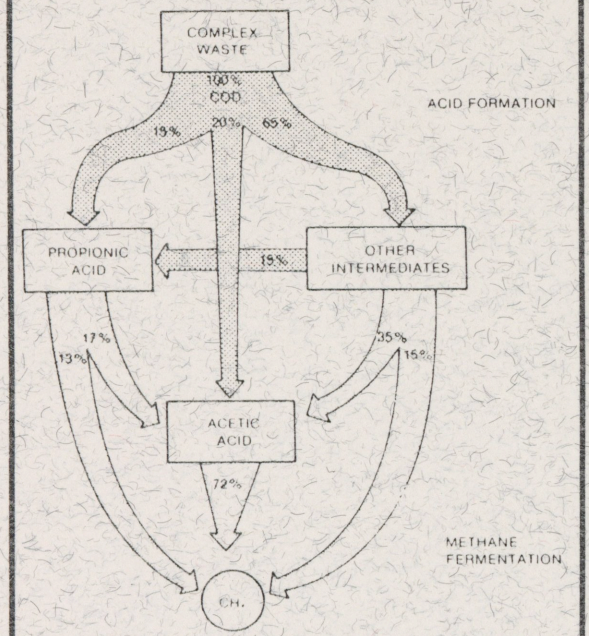
SOURCE **Heating with Wood**. Publication #016. National Center for Appropriate Technology

Wood wastes and by-products can be used in the production of heat and gas. Wood is usually measured in cords, which is equal to a stack of wood 2 x 8 x 8 feet = 128 cubic feet. About 30 percent of this is air. One pound of dried wood has a heating equivalent of 8,600 BTU. It takes 1.4 pounds of wood to equal one pound of coal or 20.7 pounds of wood to equal one pound of oil.

Wood burning has several factors that are important to the efficient use of wood energy. The first is that there is enough heat to sufficiently burn all gasses released from the wood fuel. The next important factor is to have an adequate supply of air. If this air is taken from the room being heated there will be a large heat loss from the room because the air will be replaced by cooler infiltrated air. It is best to have an outsit air source. In wood stoves over 70 percent of the heat energy is lost through the exhaust pipe. For efficient use of the lost energy in the stove pipe there should be a heat exchanger. This will force room air through a finned device which is heated by stove exhaust.

Alcohol fuels are the third possible area of biomass production. Experts in fuel technology claim that most of todays fuel needs can be met with alcohol distilled from agriculture surpluses, timber waste, municipal garbage, and waste paper. With small modifications todays automobiles can run entirely on alcohol fuels. This technology is not a new one. The Europeans have been producing alcohol fuels since 1930. Alcohol is desirable because it increases the octane level and also reduces fuel consumption of the automobile. Ethanol is the most common type of bio-fuel.

Pathways of Methane Formation From Complex Organic Wastes



SOURCE: **Other Homes and Garbage: Designs for Self-Sufficient Living**, Leckie, et. al., Sierra Club Books, San Francisco, 1975

BIOMASS

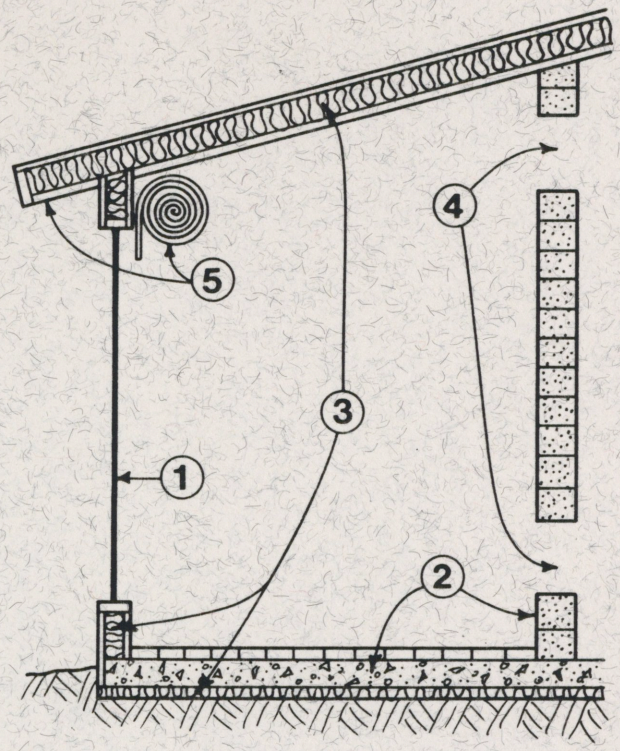


Figure 1. Sunspace features:

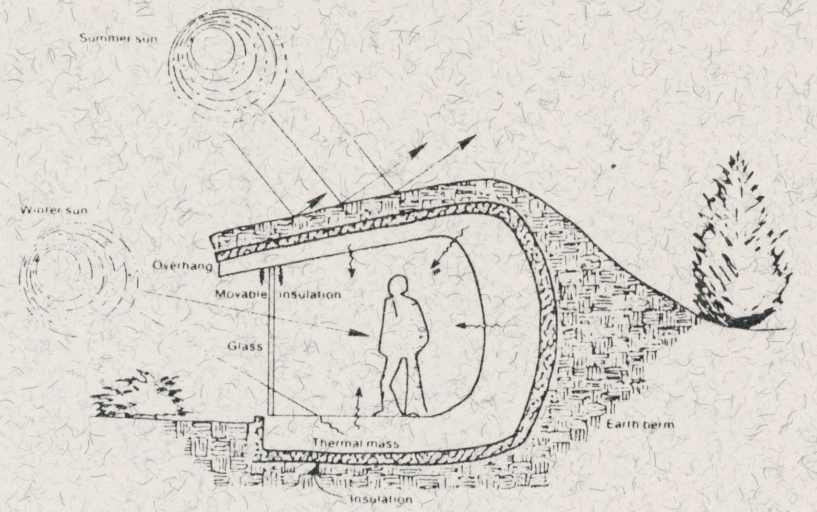
1) South-facing glazing
2) Thermal mass
3) Insulation
4) Vents for heat distribution
5) Shading devices

Passive Systems

When we talk about passive solar many people think of some high tech equipment that traps heat and energy for our homes. But in all actuality passive solar is as common as the automobile. When the sun shines through the wind shield of a car the inside of the car builds up heat energy . This build up of heat energy is the same as solar systems in many homes. The sun shines through windows and is stored in a some type of massing such as water or masonry. Then later the energy is reradiated as heat.

The main difference between a passive system and an active system is the active system is reliant on machinery such as fans, pumps, and plumbing. These elements must be very carefully designed and must have a long life cycle. This makes a passive system more attractive because of the lower initial cost and lower maintenance costs.

Direct Gain Passive Solar System

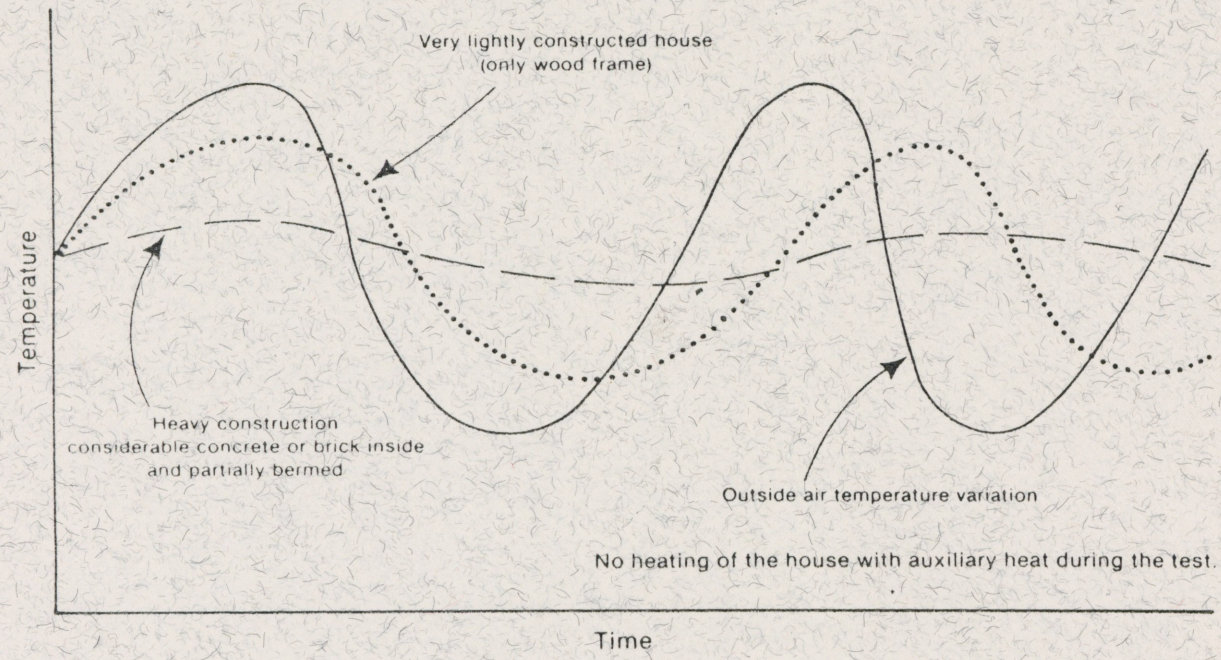


Design principles: Southern orientation of glass, unshaded in winter, protected against hot summers by man-made or natural shade. Thick, heavily insulated walls.

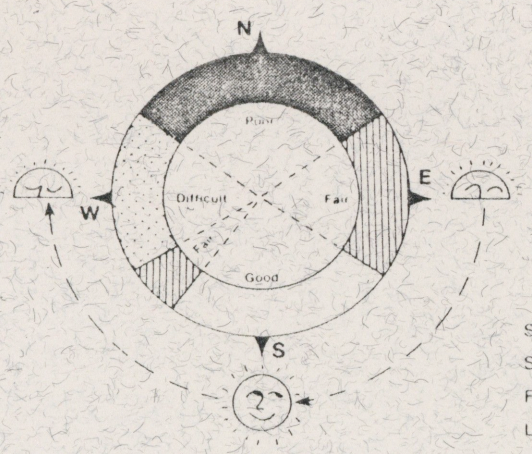
Source: Passive Solar Heating of Buildings, J. D. Balcomb et. al., Los Alamos Scientific Laboratory, Los Alamos, NM.

There are many variables that affect the passive system efficiency. The most critical variable is the positioning of the building's collector space in line with the path of the sun. Another important variable is the glazing, the thickness, number of panes, and shading devices. The composition of the thermal mass, and the architectural design of the building areimportant for optimun energy gain. We will look at three types of passive systems; direct gain, thermal storage, and green houses. The considerations will be sizing, application to homes, performance, and costs.

Temperature Fluctuations Over Time as a Function of Construction



Orientation of Living Spaces



Space	Orientation							
	N	NE	E	SE	S	SW	W	NW
SLEEPING	•	•	•	•	•	•		
SOCIAL				•	•	•		
FAMILY				•	•	•	•	
LIVING				•	•	•	•	
FOOD PREP		•	•	•	•			
PLAY SPACE				•	•	•		
STUDY		•	•	•	•	•	•	•
WORK/HOBBY		•	•	•	•	•	•	•
BREAKFAST			•	•				
LUNCH				•	•	•		
DINNER			•	•	•	•	•	
STORAGE	•	•					•	•

Orienting major-use rooms to the southern, or warmer exposure, makes maximum use of the solar energy.

An eastern exposure is second best, making the most of the morning sun. Southwestern exposures are adequate.

Western exposure presents difficulty in controlling low-lying late afternoon sun, and is also often the source of prevailing winds.

Northern exposures receive no direct solar radiation and therefore should be consigned to infrequently used spaces and those which require little or no heat. Spaces that are heated to a very low level or not at all offer very good insulating layers for these exposures.

If maximum shading from the sun is desired, the opposite from the above would apply, with easterly and northerly exposures being favored.

Source: **Your Energy Efficient House**, Anthony Adams, Garden Way Publishing, Charlotte, Vermont, 1975.

PASSIVE SOLAR SYSTEMS

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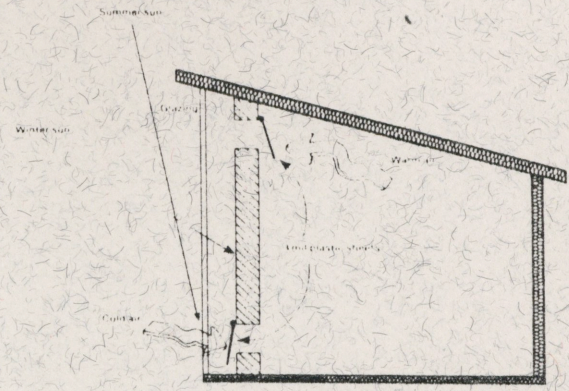
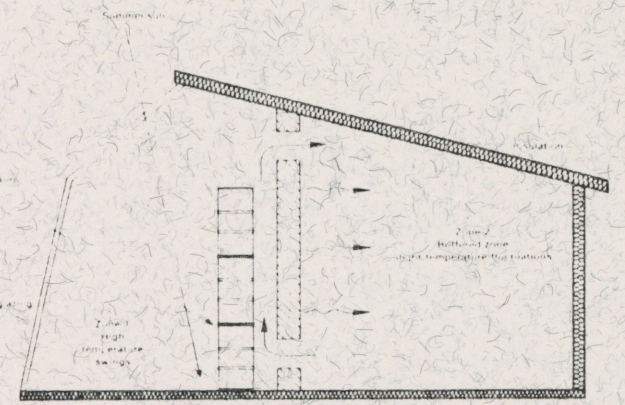
Direct Gain

The simplest passive system is the direct gain system. This direct gain is a system where there is considerable south facing glass, and massing probably in the form of masonry or concrete floor. In this system the sun goes through the glass and is captured in the floor. Later the energy is reradiated as heat. The sun angles are low in the winter when the most energy is needed, and in the summer the sun is high and the massing is shaded from the sun. This arrangement is comfortable year round due to the sun angles. Also night insulation can improve on the performance of the system. In northern climates night insulation is critical.

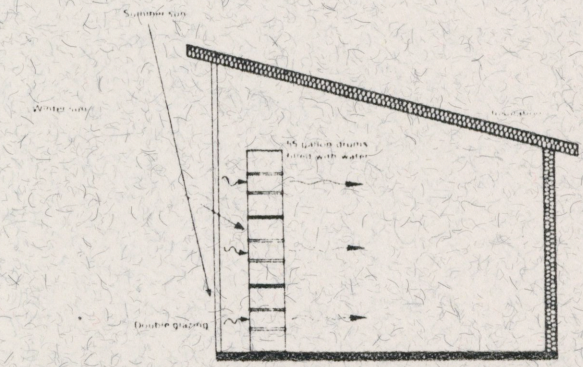
Trombe Wall
with Operable Vents



Attached Solar Greenhouse



Waterdrum Wall



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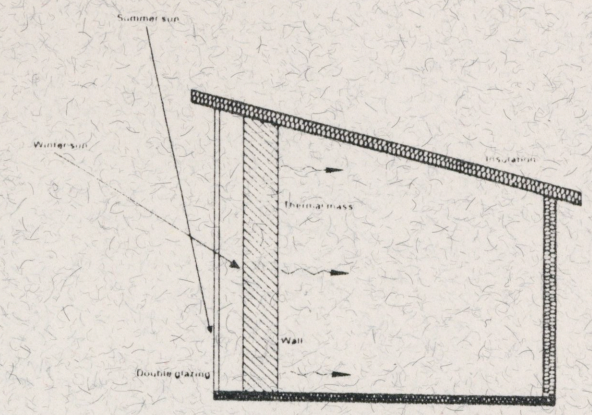
PASSIVE SOLAR SYSTEMS

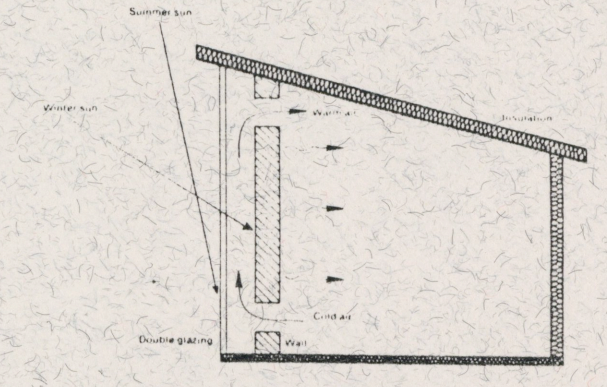
Thermal Storage Wall

A second type of passive system is the thermal storage wall. In this system the thermal mass is just several inches behind the south facing glazing. The mass is usually painted a dark color to increase the effectiveness of the massing. The best massing is usually water storage or masonry of some type. During the day the sun's rays heat up the mass and the heat travels through the wall and is radiated in to the interior of the house. Another variation of the thermal mass wall is the Trombe wall. The Trombe wall not only radiates heat through the wall but also convection currents circulate heat off the suns side of the wall to the interior of the structure. As the air is heated between the glazing and the thermal mass it rises to the top and moves through vents. The heated air is the replaced with cooler air from the floor of the interior room. This convection of air provides about 30% of the total energy that is supplied to the interior rooms.

Thermal Storage Wall



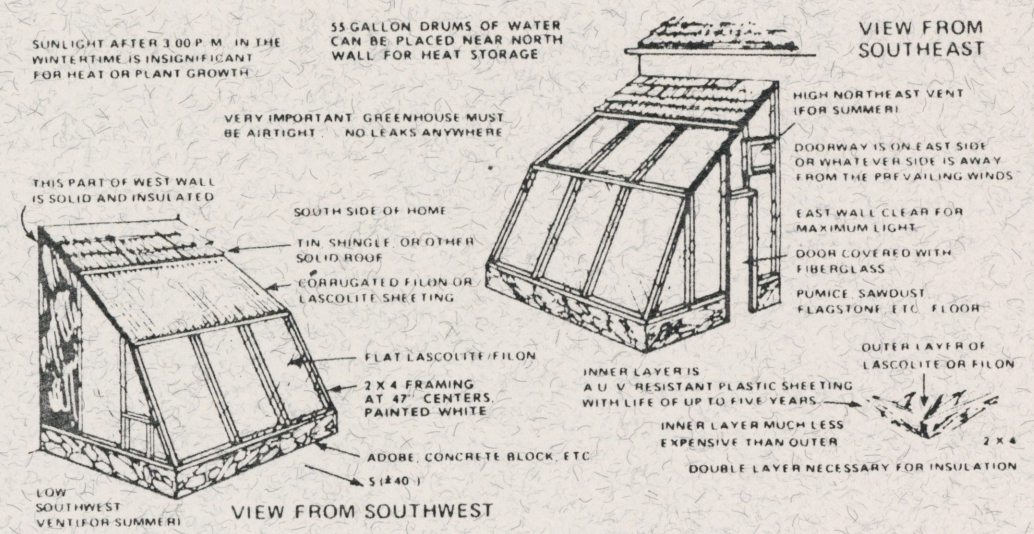
Trombe Wall



Greenhouse

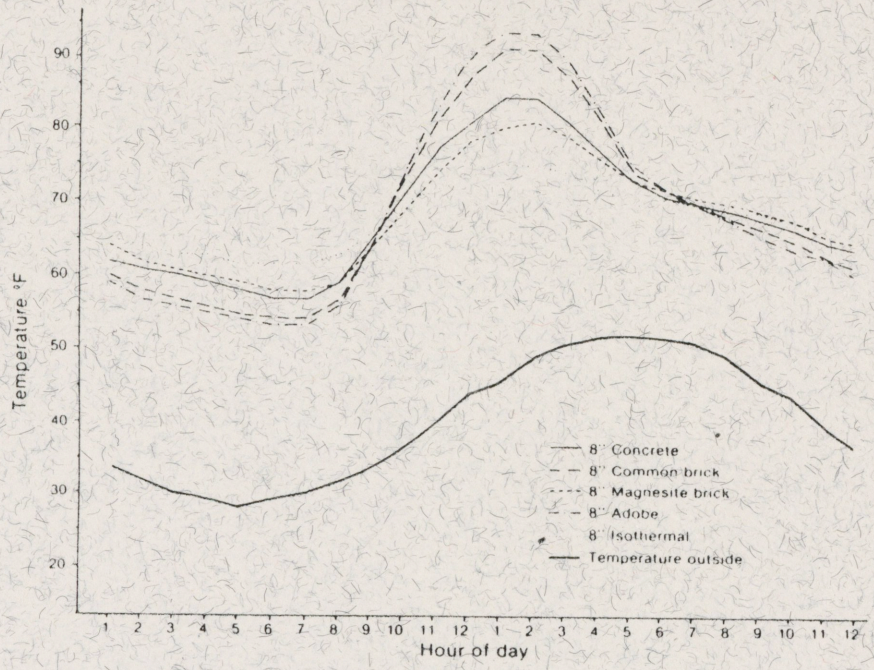
The third type of passive solar system is the solar greenhouse. The greenhouse system combines the advantages of both the direct gain and the Trombe wall systems. Plus it also gives you the added advantage of the extra floor space. This space can be an excellent space for horticulture, and gives year round opportunities for gardening. The only drawback to this type of space is that the temperature swings can be large at times. This type of system can be attached or separate from the main structure.

Basic Solar Greenhouse



Source: **An Attached Solar Greenhouse**, W. F. Yanda. Lightning Tree, Sante Fe, New Mexico. 1976

Comparison of Thermal Materials



Source: **Predicting the Performance of Passive Solar Heated Buildings**, Ed Mazria, et al., Architectural Department, University of Oregon, 1977

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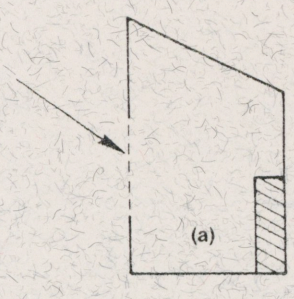
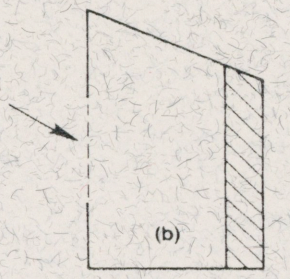
Thermal Mass Configurations

temperature fluctuation
50° — 90°F.



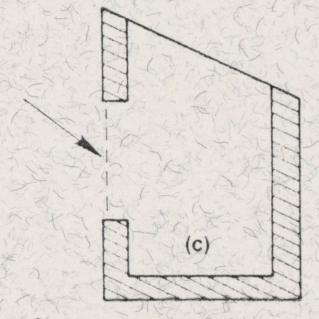
8" mass
mass surface equal to glazing area

temperature fluctuation
65° — 85°F.



8" mass
mass surface area 3 × glazing area

temperature fluctuation
60° — 70°F.



4" mass
mass surface area 9 × glazing area

Sizing Passive Systems

Sizing the components of the passive system is critical for the optimum performance of the system. The factors that need consideration are; the square footage of south facing glazing, and the amount and composition of massing. Also an important consideration is the use and type of night time insulation. The amount of space that is being heated will also be a determining factor. The size and composition of the massing will determine the amount of heat energy that can be stored and the time and rate at which the energy will be released.

The overall goal in designing passive solar systems is to reduce the temperature fluctuations in the space being heated, this in turn will reduce the amount of purchased energy needed. The only control of a passive heating system is the correct sizing of the massing and south facing glazing. If night time insulation is used you will have more control of the temperature fluctuations. The temperature fluctuations of diferent construction types can be seen in the chart on the previous page. This can be calculated with the use of what is called the balance point temperature of the structure. A home with a lower balance point temperature would be better insulated and have higher heat gains and thus would require less purchased energy.

Doug Balcomb, who does solar research at LosAlamos Scientific Laboratory, has developed the following rules for the design of passive solar energy systems.

Number one is 2 to 3 square feet of south facing glazing should be used for each BTU/°F-hr. of additional thermal load. This will give at least 50 percent solar heating in Montana for a building kept within a temperature range of 65 degrees to 70 degrees F.

Number two is a thermal storage capacity of at least 30 pounds of water or 150 pounds of masonry or rock for each square foot of south glass. The storage should be located in direct sun light, if not there will be a need to increase the massing by four times.

Number three is the best thickness of the storage is in the range of 10 to 12 inches. Also the masonry should have at least 100 pounds per cubic foot density. Thermocirculation vents can be used to increase day time heat gains, and light weight back draft vents to prevent night cooler night time air from entering the living spaces.

Also in Montana, large overhangs are not important because the sun reaches such high angles, and too large of an overhang will decrease the amount of energy that can be trapped in the solar system.

A passive system can have a 35 percent efficiency in converting sun energy to heat energy which is about 5 percent higher than active systems.

There is not a lot of technical data on passive solar systems in the northern latitudes but research is continuing and data is coming in every day. Testing is being done at Butte N.C.A.T. (National Center for Appropriate Technology). Also many computer programs have been developed for the testing and analysis of passive systems.

Direct Gain vs. Trombe Wall Systems

DIRECT GAIN

Advantages

- scenic view remains intact
- high efficiency of conversion of incoming light to usable heat

Disadvantages

- glare
- intense light can fade materials and furniture finishes
- cannot use rugs on floor or the storage area will be curtailed
- a large (expensive) amount of masonry is necessary
- easy to overheat in the winter
- difficult to maintain temperature control

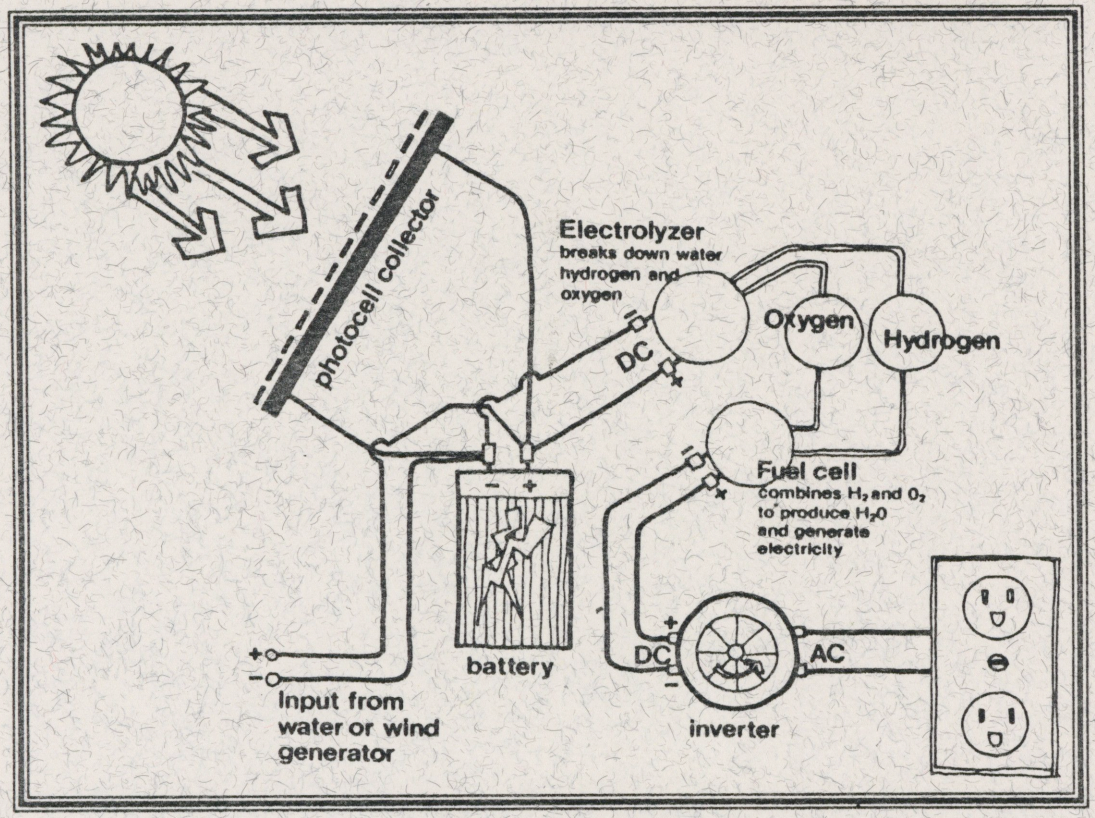
TROMBE WALL

Advantages

- minimizes concrete
- less temperature fluctuation than in a direct gain system
- better and easier temperature control than direct gain

Disadvantages

- loss of view to the south
- cannot use the wall to hang pictures, etc as that would decrease the effect of the thermal mass
- can lose heat back through the trombe wall
- loss of solar spots



PHOTOVOLTAICS

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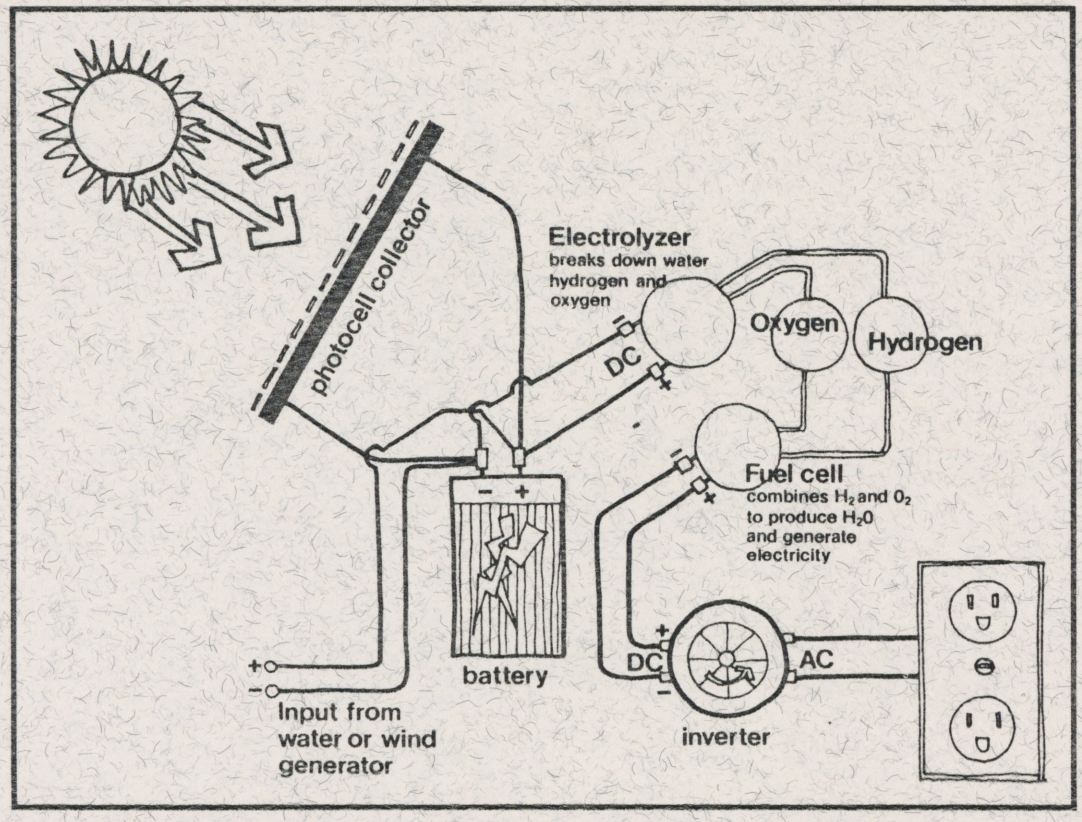
Photovoltaics

Photovoltaic cells are a semiconductor device in which the absorbtion of light creates a separation of electrical charges. This results in an electrical potential that can be tapped by allowing electrons to flow through an external circuit. The net effect is the direct conversion of light into electricity.

Photovoltaics have in the past been developed mainly for space exploration and satellites. For all other applications photovoltaics have the disadvantage of being extremely expensive. New techniques for growing the crystals used in photovoltaic cells are reducing the cost, and production techniques are bringing down the cost of these cells.



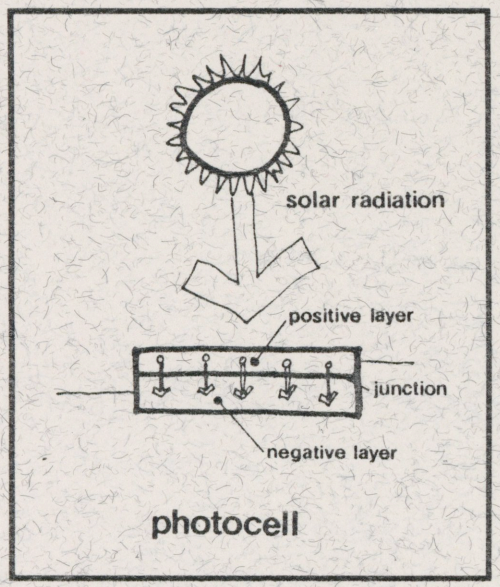
In some solar applications the cells are mounted on a surface with water collectors behind them. The water collectors help keep down the temperature of the cells. The output of the photovoltaic cells increases as the temperature rises to about 82° C (180° F) and then drops rapidly.

The photovoltaic cells generate direct current which can be stored in a bank of batteries. The current must then be converted to alternating current for use in the home.

Silicon for photovoltaic cells is grown in large single crystals, then wafer thin strips are carefully sliced from the crystal to form the basic unit of the cell. The cell is then coated with another material called boron, to produce a positive electrical layer which interacts with the negatively charged silicon layer.

When photons, which is the primary energy of light, strike the cell, they are converted to electrons. Then the interaction of the silicon and the boron creates an electrical current.

One of the advantages to photovolaics is that a wind generator can be added easily without extra support equipment.



photocell

LANDSCAPING

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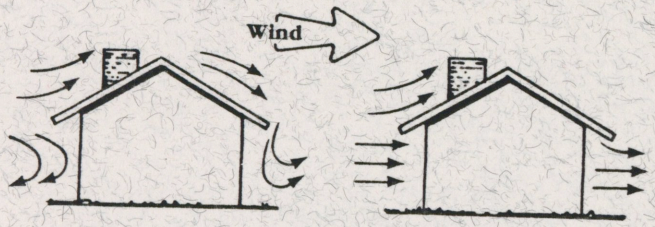
LANDSCAPING TO CUT ENERGY COSTS

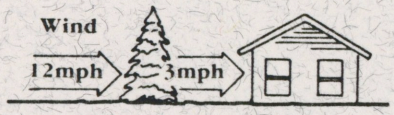
Through proper use of trees and shrubs, the natural terrain and man made structures, energy needs can be reduced. This is accomplished by shading from the sun and protecting from the wind.

An unprotected structure loses more heat energy on a cold windy day than on an equally cold calm day. By carefully locating tress and shrubs wind can be slowed down and reduce the convective heat loss effects of the wind. Infiltration can account for as much as one third of the heat loss. This infiltration is increased by the wind presure. Wind breaks and foundation plantings can reduce the air presure that cases infiltration.

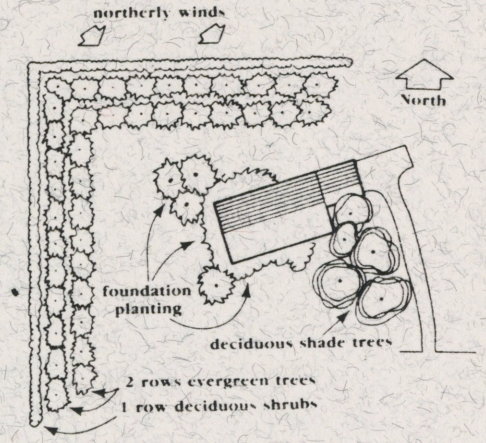


Wind increases the convective air currents along outside walls and roof, thus increasing the home heat loss.

Infiltration effect of wind.



Studies of wind breaks show that windbreaks can reduce winter fuel consumption by 10 to 30 percent. The amount of energy that can be saved by wind breaks varies with the climate of the area, location of the structure, and construction type. A well weatherized house with adequate ventilation, caulking and weatherstripping won't benefit from windbreaks as much as a poorly constructed home.

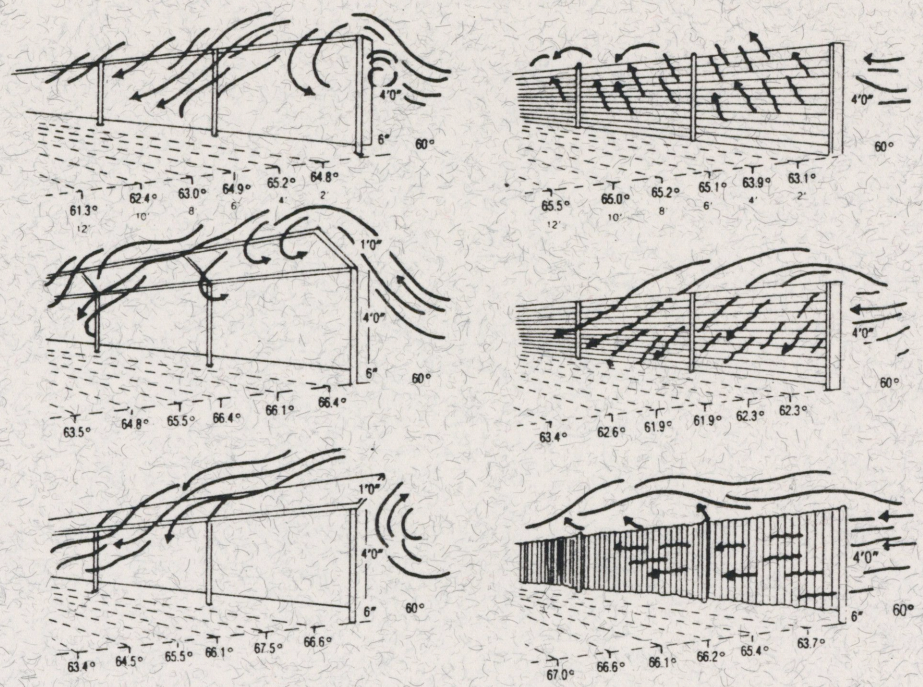


Windbreaks also reduce the wind chill effect on people outside the structure. Windbreaks can also reduce snow removal efforts if place properly.

Wind breaks must be located perpendicular to the prevailing winds. In areas where wind directions change there will be a need for multiple alignments. Windbreaks should be located from the structure approximately one to three times the height of the trees.

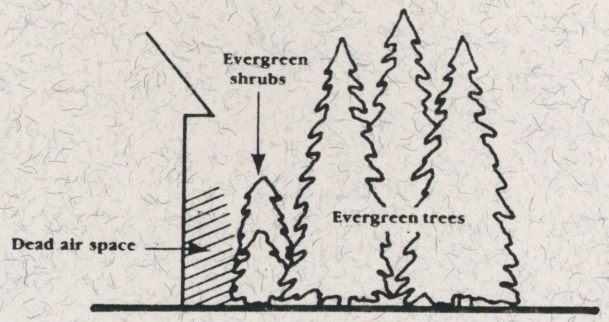
Where space is limited, a single row of conifers like spruce trees will be quite effective. However several rows are recommended. Spacing in one, two or three row windbreaks should be 6 feet between trees. With for or more rows the spacing should be at least eight feet. Rows should be ten to twelve feet apart with the trees staggered.

When reducing wind with architectural elements it is not important to stop the wind but to redirect the wind. Various types of barriers configurations have different effects on the wind flow.

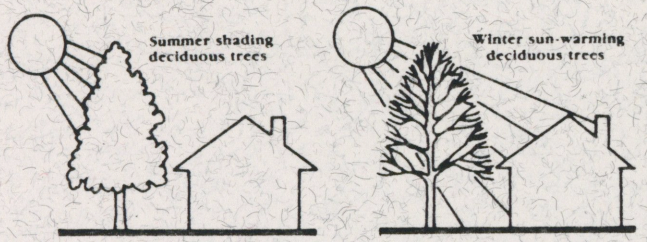


Wind control with walls and fences (Center for Landscape Architectural Education and Research).

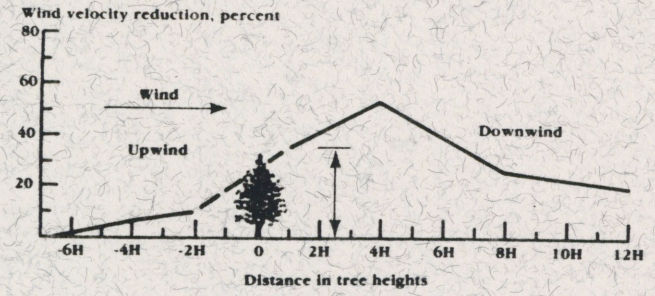
For the best summer shade locate plantings along sunny boarders of the structure. The location of the vegetation will vary depending on the location and orientation of the structure. East and west walls need protection from the low sun angles of rising and setting sun. Also the south facing roof planes need protection from the afternoon sun. Deciduous trees are best for the southern exposures because they shade the structure in the summer, and in the winter when they lose their leaves the sun can help warm the home.



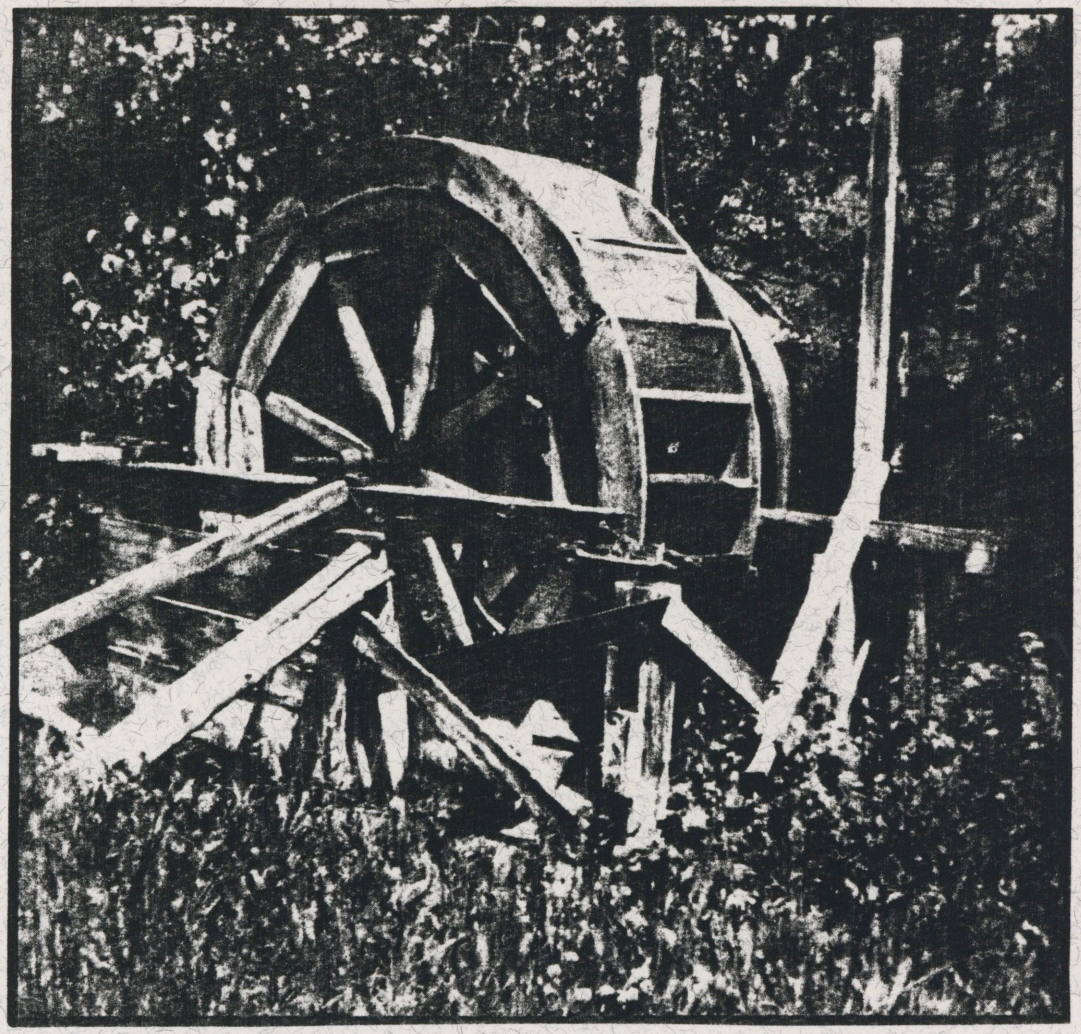
Windbreaks of two to five rows of trees and shrubs generally provide good protection. Evergreen trees provide the best protection.



During winter, deciduous trees and shrubs shed their leaves and let the sun's rays help warm the house.



A well planned landscape that combines properly placed vegetation and architectural elements can reduce energy bills. Winter heating costs can be reduced by as much as 15 percent, and summer cooling costs can be reduced up to 50 percent or more. There are four basic planning goals to consider: first maximize winter sun, second shade summer sun, third maximize summer breezes, and fourth block winter winds.



HYDRO ELECTRIC

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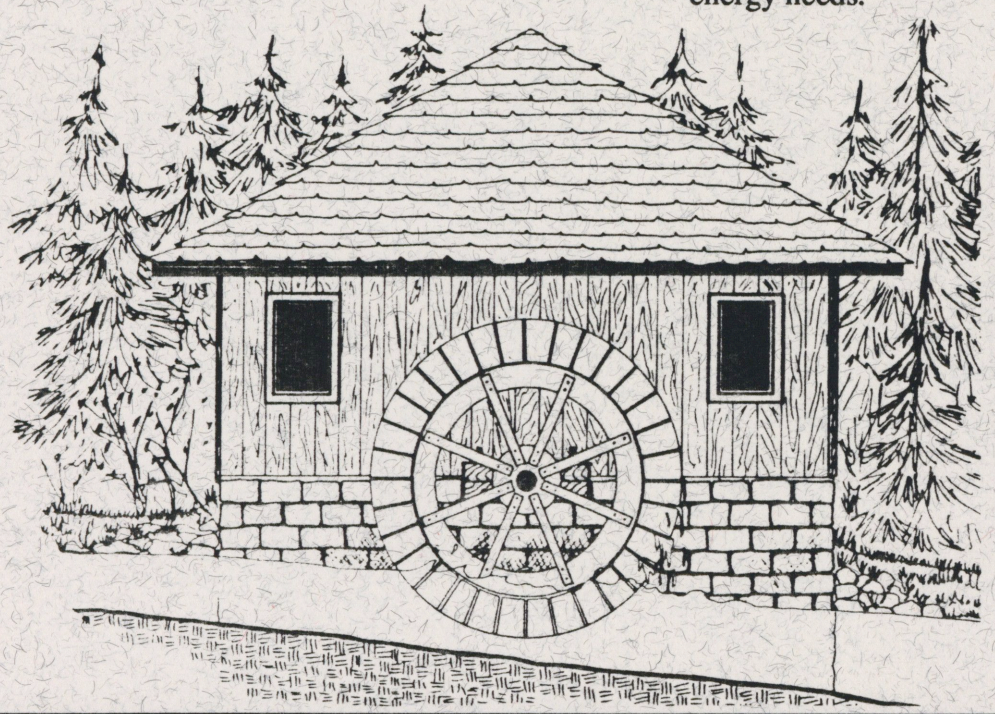
HYDRO-ELECTRIC POWER

Harnessing falling water for power is not new. The small scale hydro potential of Montana's streams and rivers is still untapped. This section will give some of the basics of small scale hydro-electric production.

In order to determine the hydro potential of a site, information on the amount and variation of stream flow is essential. A good place to begin looking for this information is The nearest U.S. Geological Survey office (USGS). In Montana the USGS is located in Helena, MT (Federal Building Phone 449-5263, zip 59626). If historic records are not available, then immediate monitoring of the stream flow is vital. The two most important factors are flow and head.

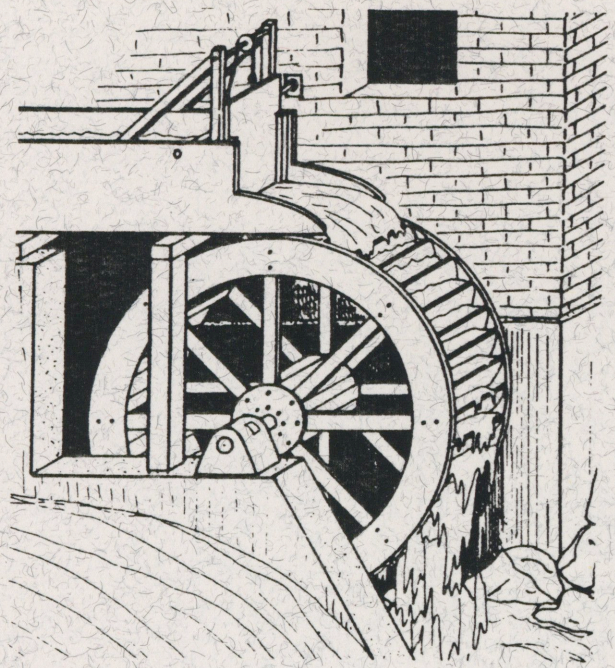
Flow is the quantity of water flowing past a point at any given time. This will vary both seasonally and annually. Also minimum and maximum flow is important. Head is the vertical distance in feet from the surface of the water supply to where the water leaves the turban. The greater the head the more energy that can be produced.

Another question to the feasibility of a hydro project is the amount of energy needed. Peak demand and consumption levels should be calculated. A system capable of meeting power consumption will not necessarily be able to meet peak energy needs.

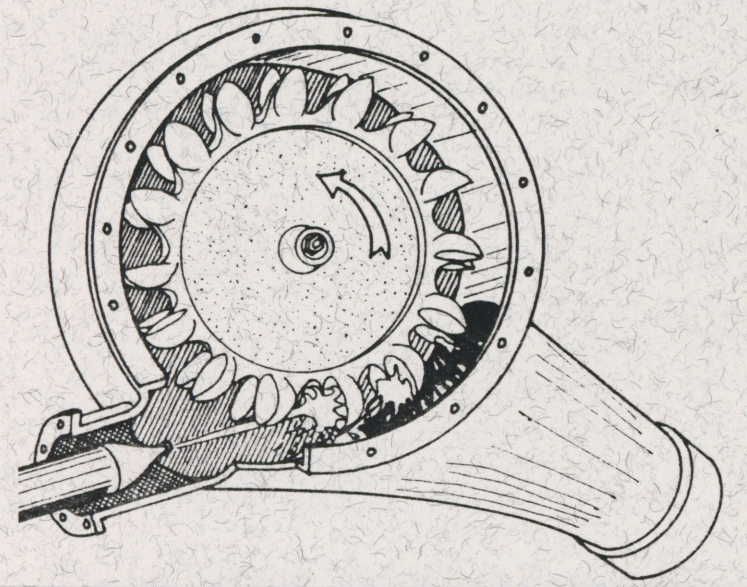


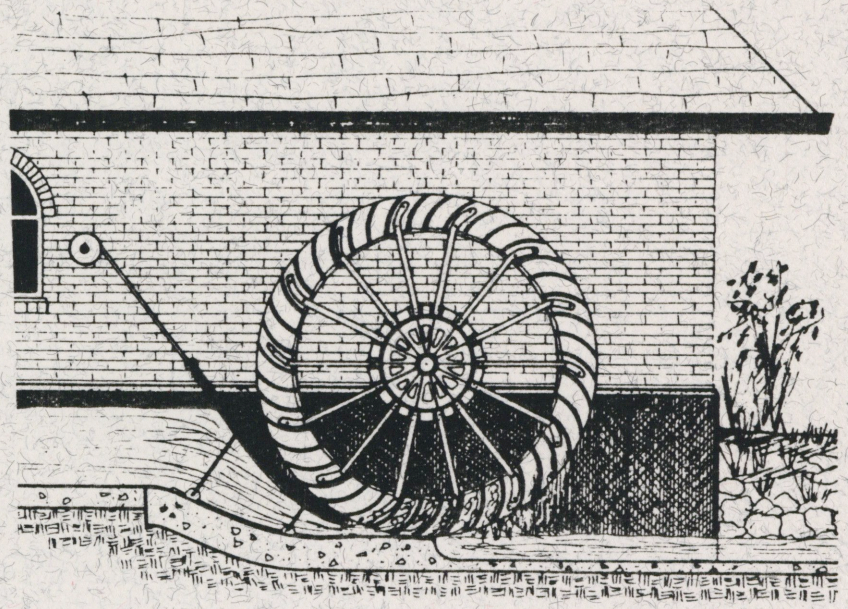
Undershot Wheel:

This is the most basic of water wheels. Water passing under the wheel strikes the blades or paddles, causing the wheel to rotate. It can operate on a minimum of one foot of head (producing almost no power at this head), and has a low efficiency. The optimum head range is 6 to 15 feet, with minimum wheel diameter being about 15 feet.



Water wheels and water turbines are the two basic types of hydropower machines. There are several advantages of water wheels. One advantage is that water wheels can be used if there is a large change in water flow. And the second advantage of water wheels are there is not a problem with debris. One disadvantage is because of the slow rotation, there is need for gearing to produce rotation speeds required for electric generators.





HYDRO ELECTRIC

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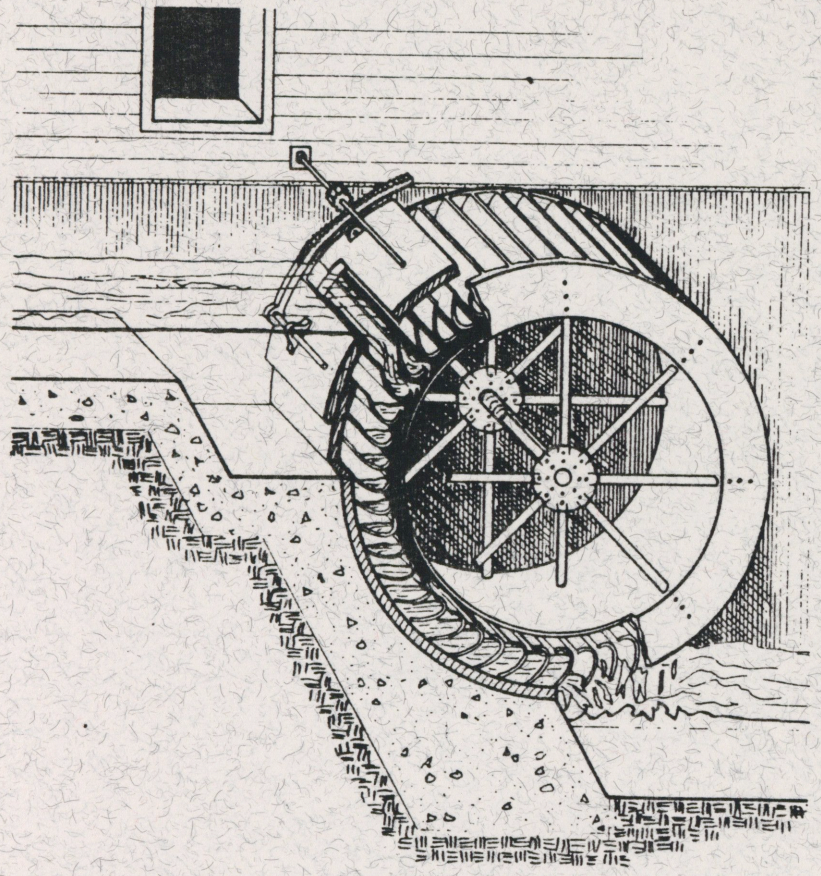
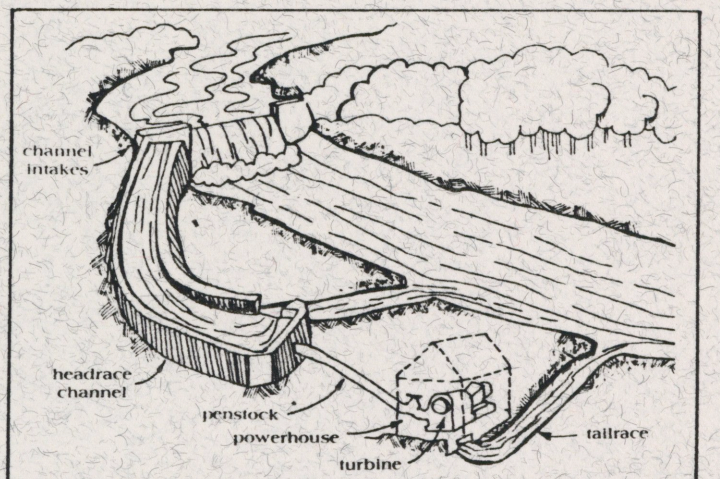
HYDRO ELECTRIC

Water turbines spin at high speeds to produce electricity. The water turbines ca be 70 to 80 percent efficient. Turbines receive their energy from water carried in pressure conduits. Water turbines are complicated pieces of equipments and must be installed with great care. Debris such as rocks, sticks, and sand can interfere with the operation of the turbine blades. The debris must be screened out before it is allowed to inter the pressure conduit.

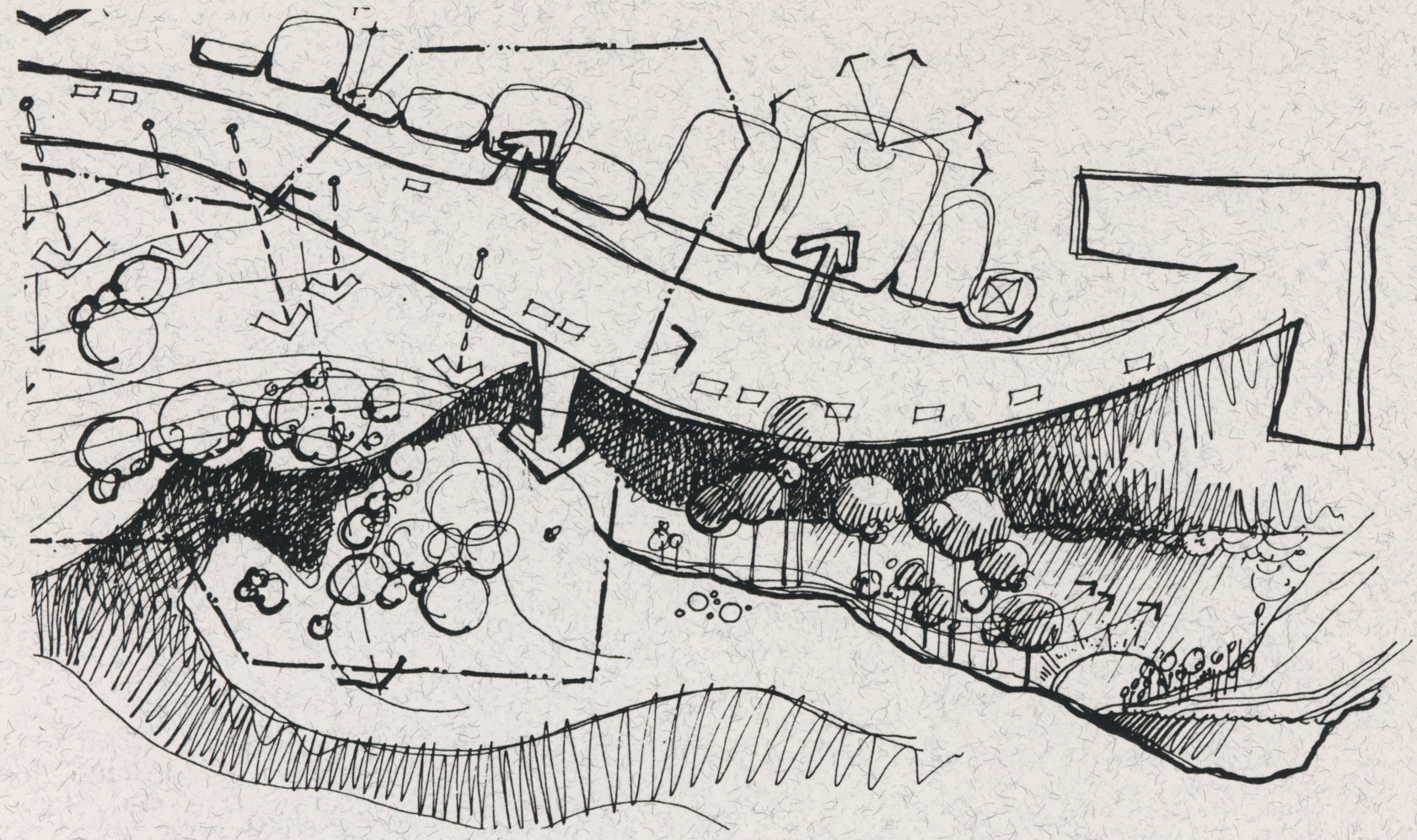


There are several components of the hydroelectric system. an intake structure that controls the flow of water. A penstock or flume that carries water from the intake to the turbine. And the power house which contains the turbine, generator, and controls.

Costs of installing a hydroelectric system varies widely. Typical costs range from $1,000 to $3,000 per kilowatt, installed. There are also environmental considerations like water access and water shed. Also the effects of damming of the stream, and disruption of the wildlife habitat must be considered.



A typical installation for a small hydroplant. Reprinted with permission from **Other Homes and Garbage**, Jim Leckie, Gil Masters, Harry Whitehouse and Lily Young, Sierra Club Books, San Francisco, 1975.



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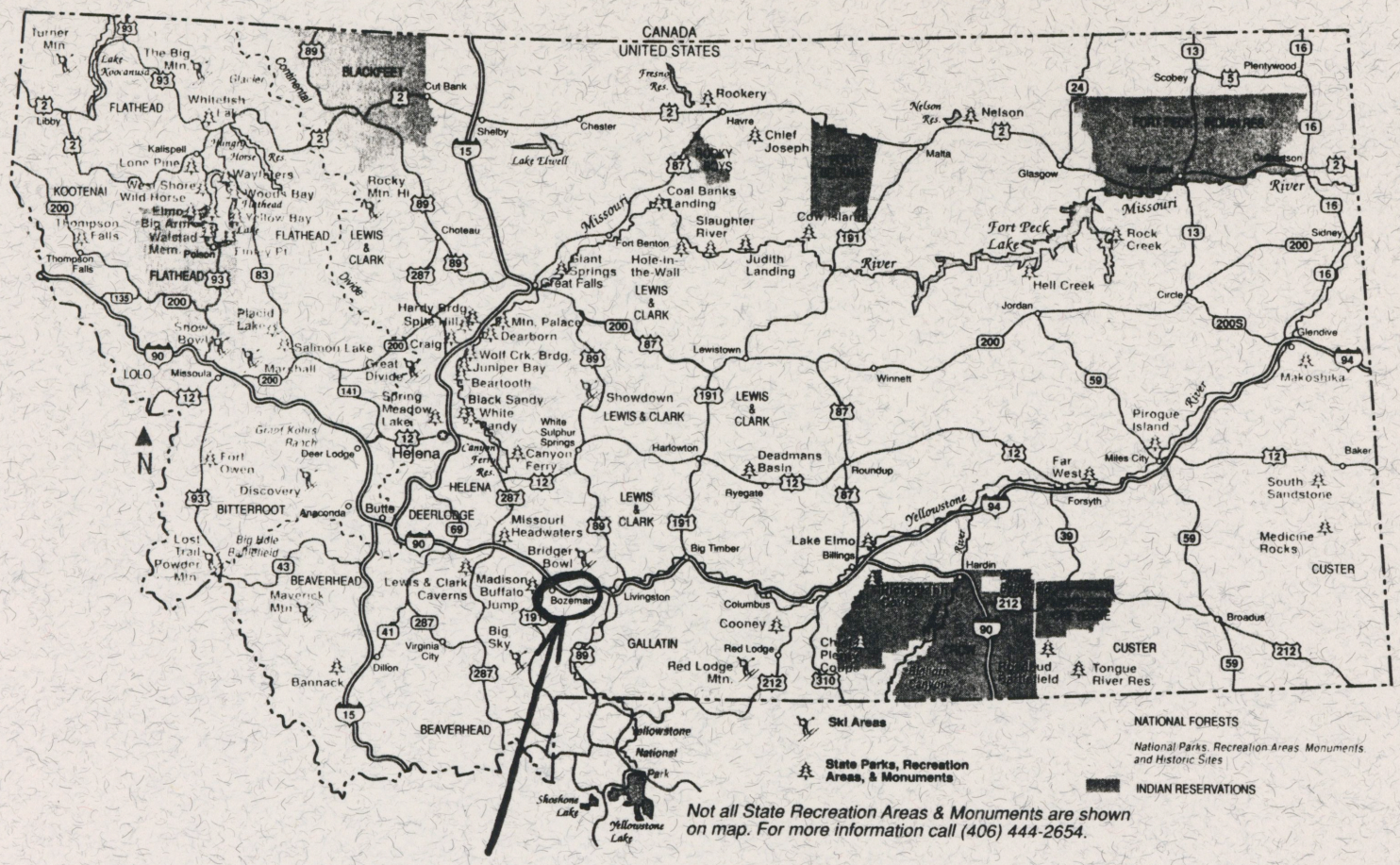
SITE ANALYSIS

LOCATION



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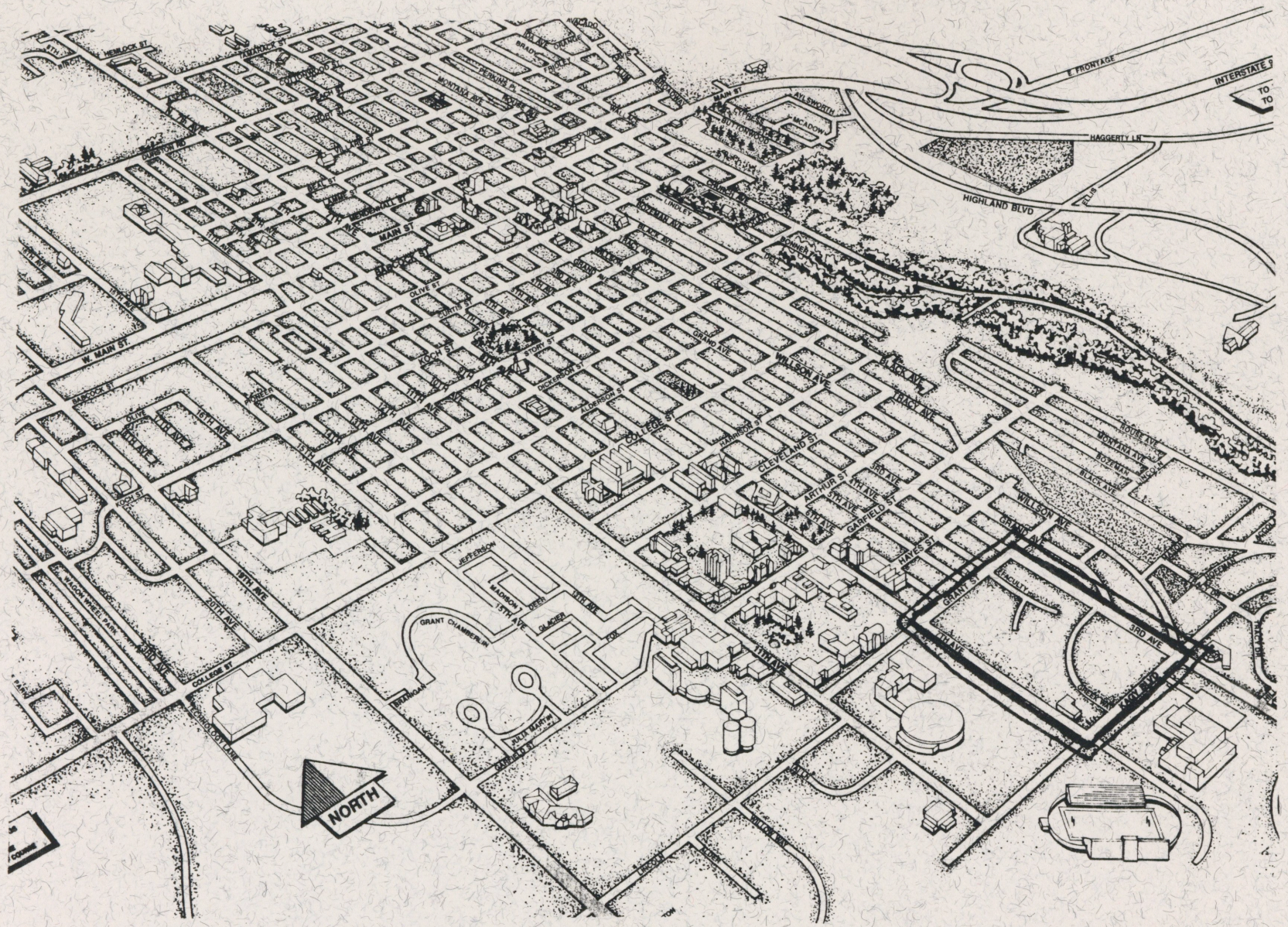

SITE ANALYSIS

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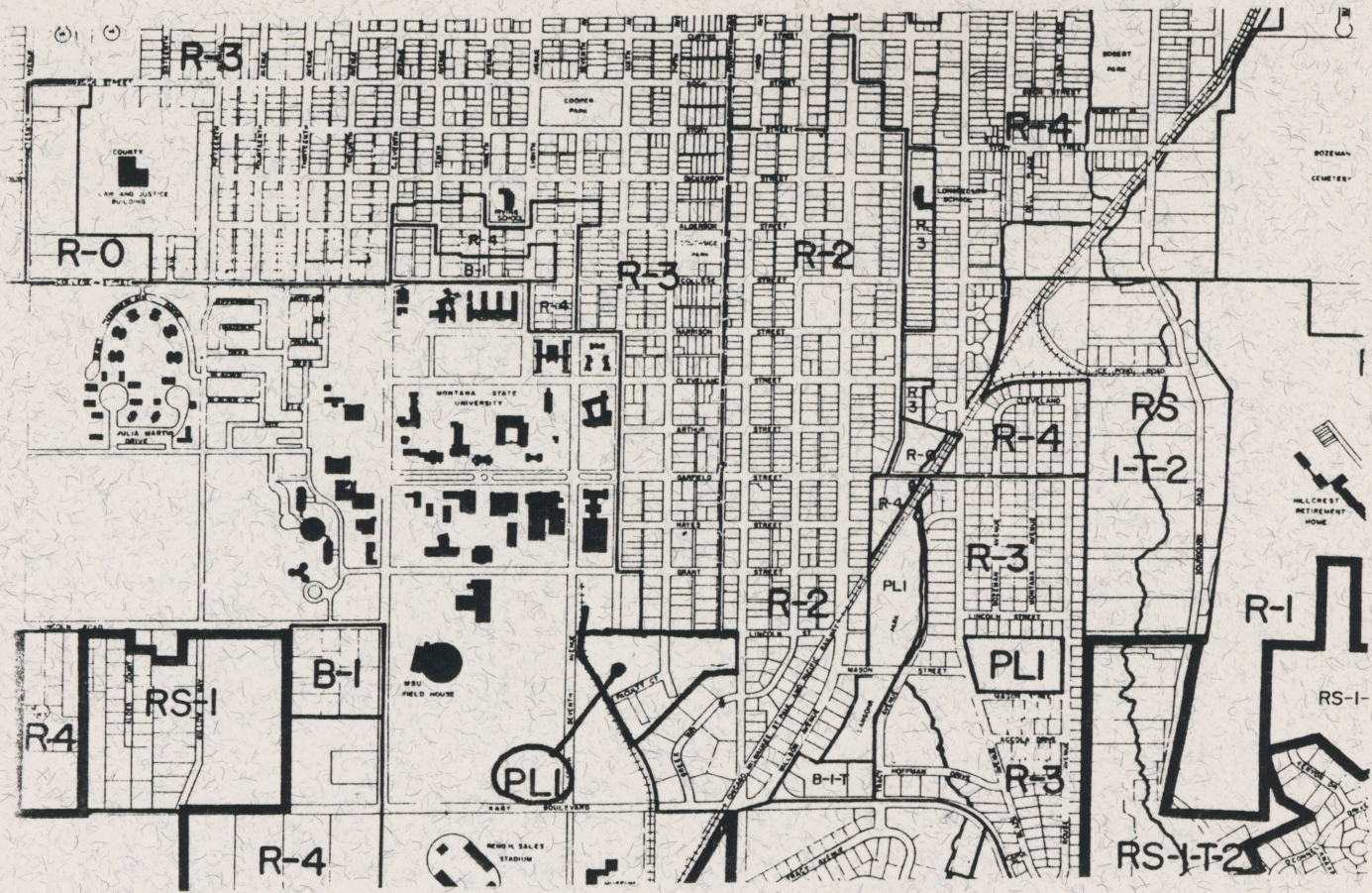


SITE ANALYSIS

A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

CLIMATE FOR BOZEMAN, MT

LAT. 45.67 degrees north LONG. 111.03 degrees west ELEV. 4754 ft.
TOTAL HEATING DEGREE DAYS 8082

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY AVE. TEMP	20.4	25.9	30.2	42.1	50.9	57.6	66.3	64.9	55.6	46.1	32.2	25.2
DAILY MAX. TEMP	30.7	35.8	41.0	53.7	63.3	70.2	81.5	80.3	69.5	58.7	42.4	34.9
DAILY MIN. TEMP	10.1	15.8	19.2	30.4	38.5	44.8	51.1	49.4	41.5	33.4	21.9	15.5
EXTREME MAX. TEMP	58.0	62.0	70.0	81.0	89.0	91.0	93.0	99.0	93.0	82.0	70.0	59.0
EXTREME MIN. TEMP	-36.0	-29.0	-23.0	2.0	16.0	26.0	32.0	29.0	16.0	9.0	-26.0	-29.0
HEATING (65) DEGREE DAYS	1372	1106	1074	680	429	232	45	70	288	581	976	1229
COOLING DEGREE DAYS	0	0	0	0	0	23	125	100	25	0	0	0
AVE. HIGH % REL. HUMIDITY	65	65	61	60	59	59	48	47	57	58	63	65
% POSSIBLE SUNSHINE	49	57	68	63	64	65	81	78	67	61	46	46
MEAN CLOUD COVER (0-10)	7.3	7.4	7.2	7.4	6.9	6.5	4.0	4.6	5.7	6.3	7.2	7.2

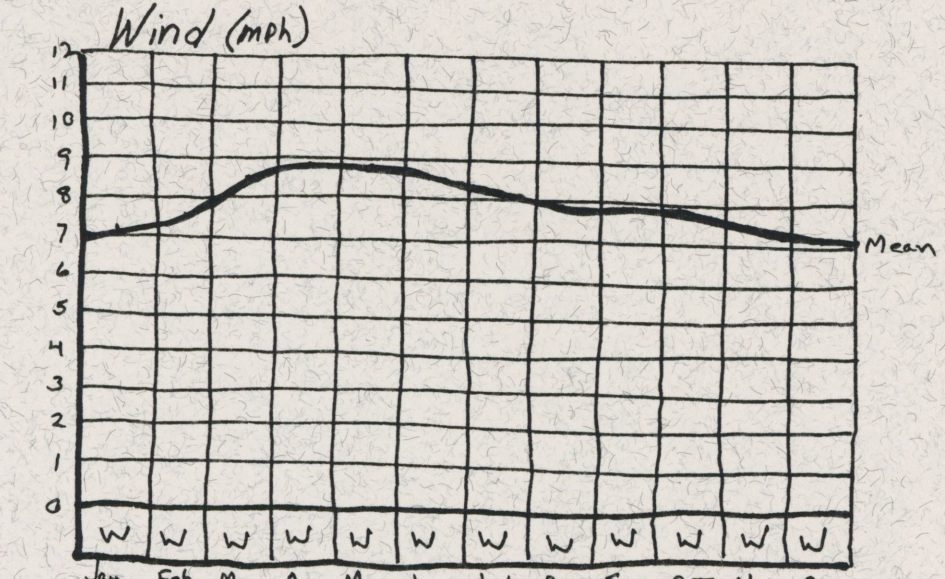
SUN ANGLES: DEC. 21 21 Degrees (noon) JUNE 21 68 Degrees (noon)
PREVAILING WINDS: Winter NW Summer W-SW Winter Storms E
Ave. Speed: 7-9 MPH monthly

SOURCE: FOULKES ENGINEERING, 31 GARDNER PARK DRIVE, BOZEMAN, MT 59715

A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

CLIMATE FOR BOZEMAN



SITE ANALYSIS

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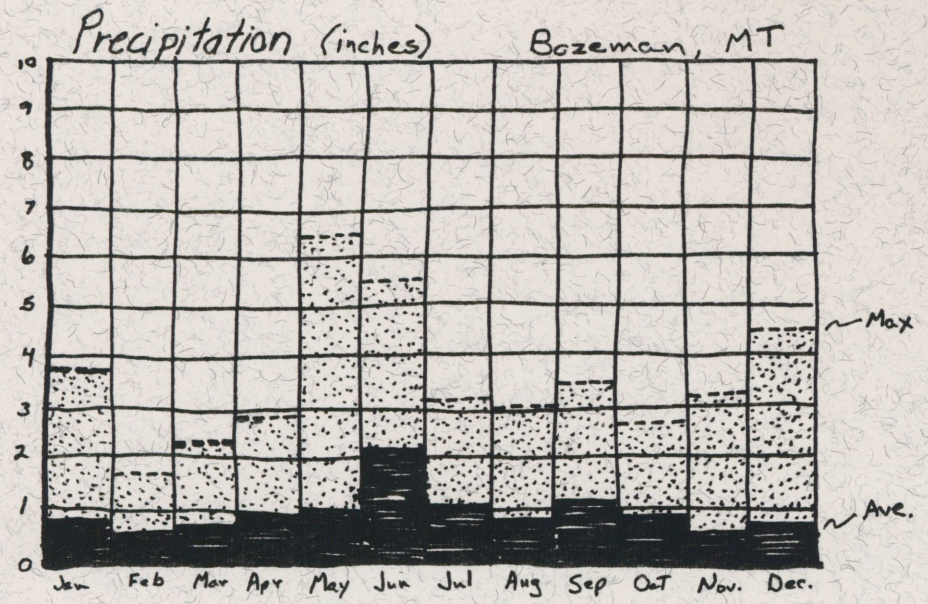

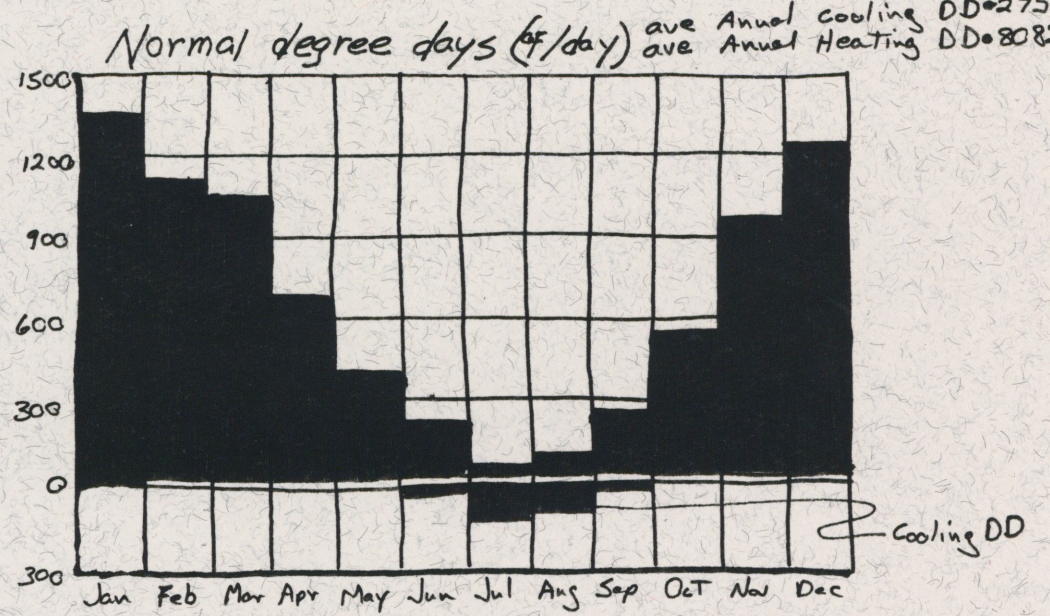

SITE ANALYSIS

A FACULTY HOUSING PROJECT

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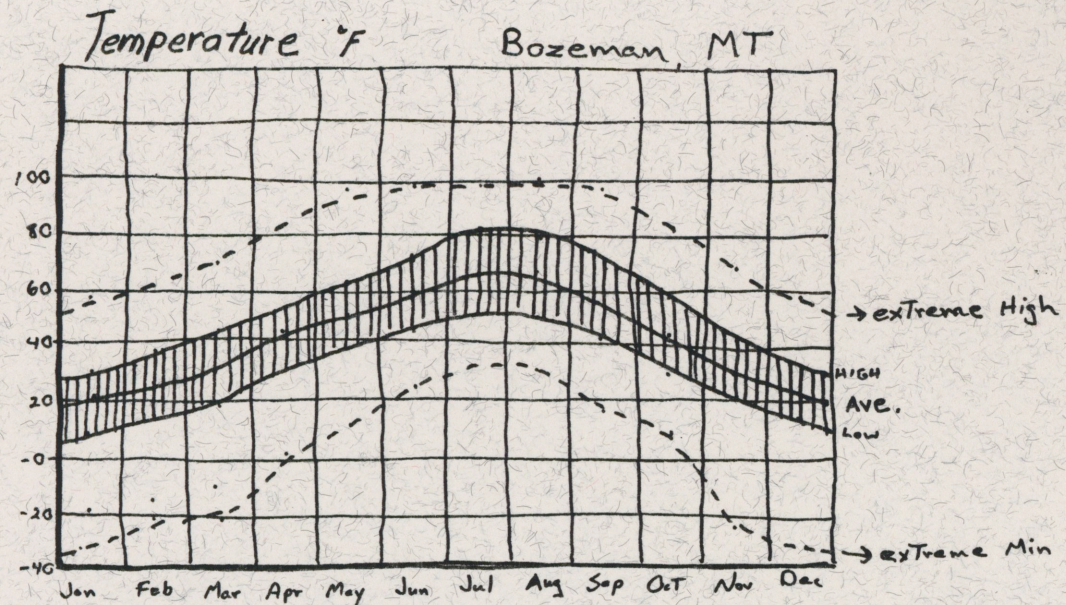

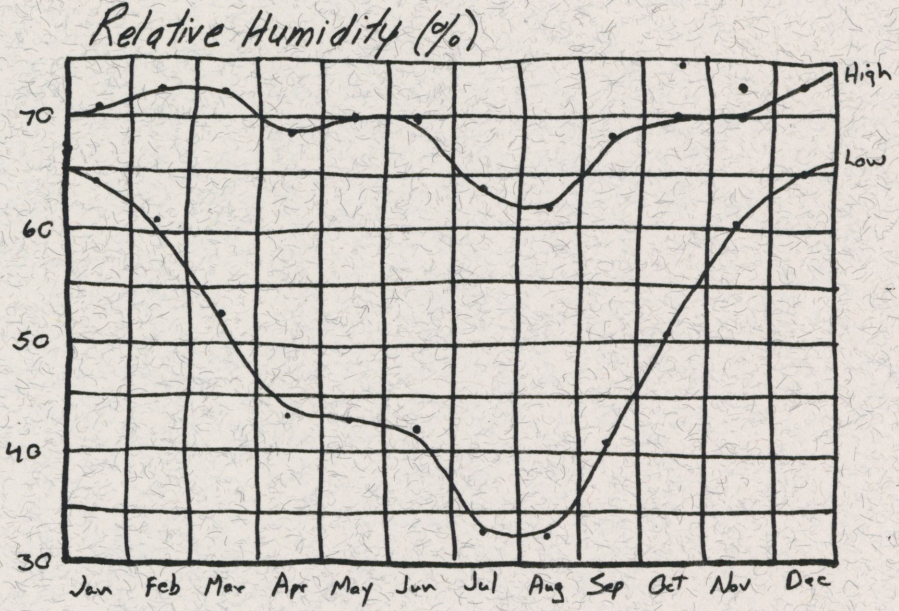

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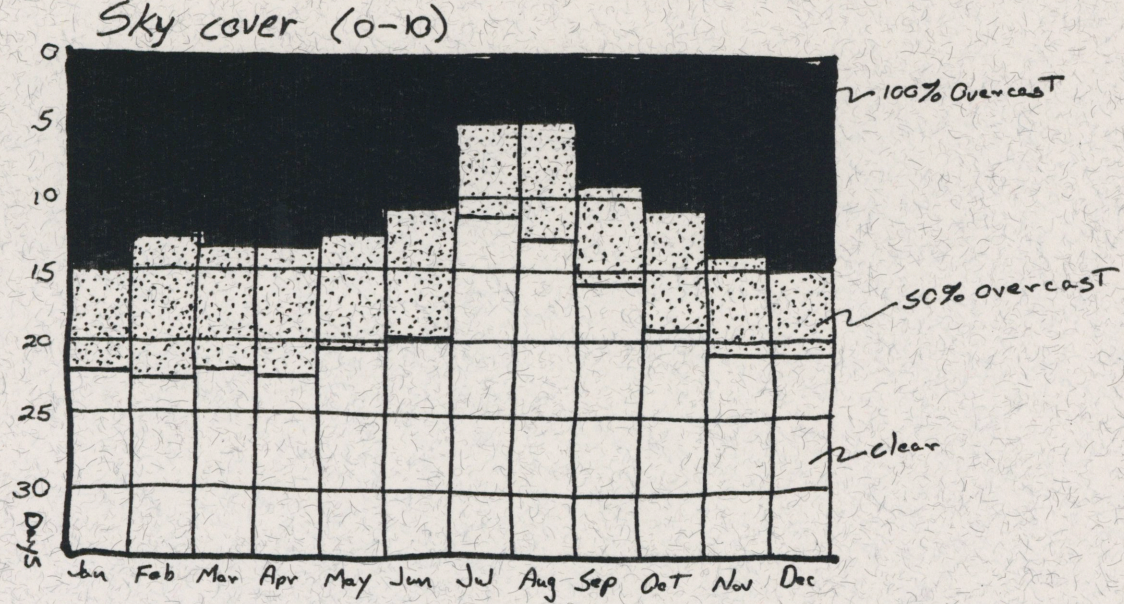
SOLAR DATA



SITE ANALYSIS

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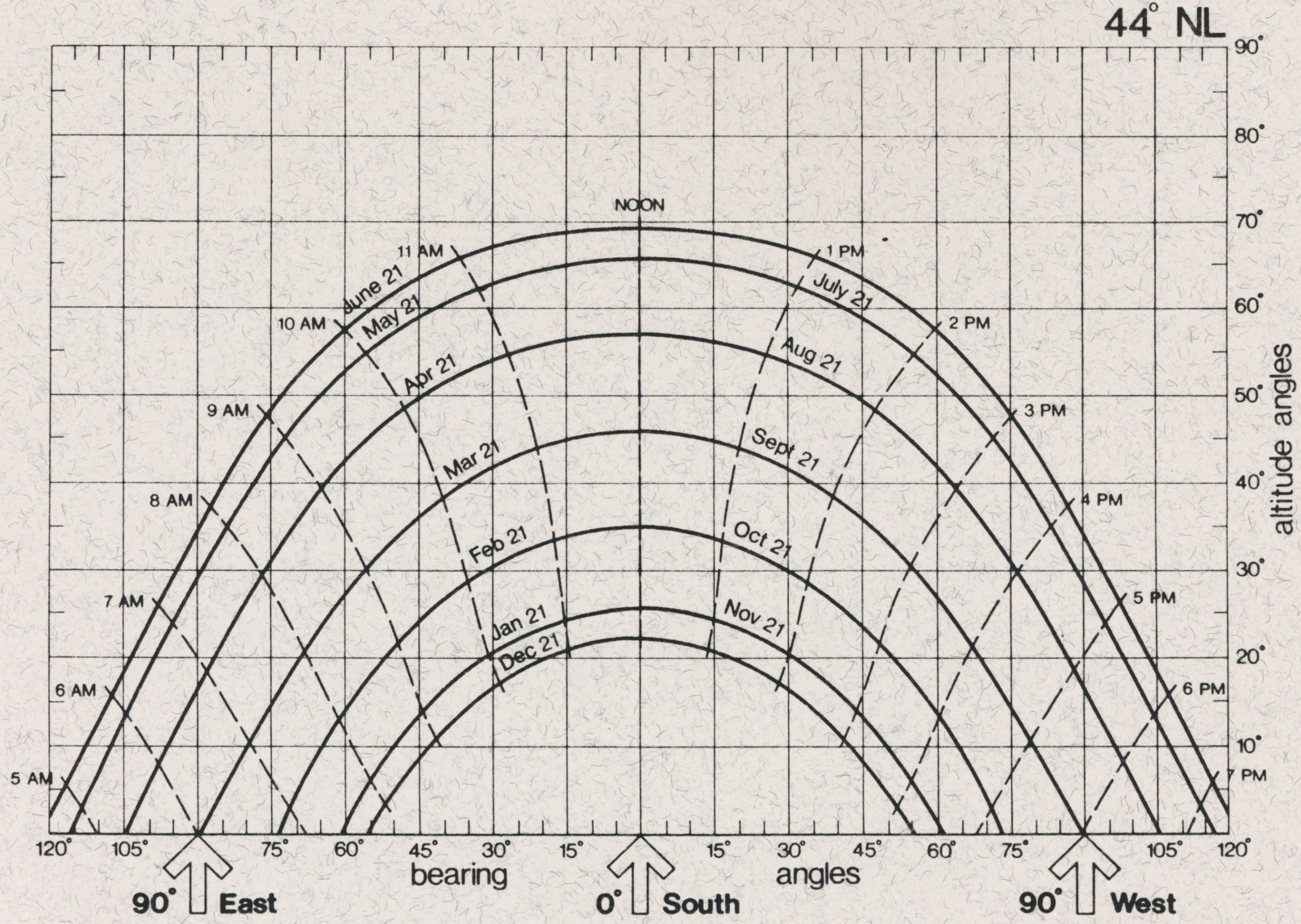
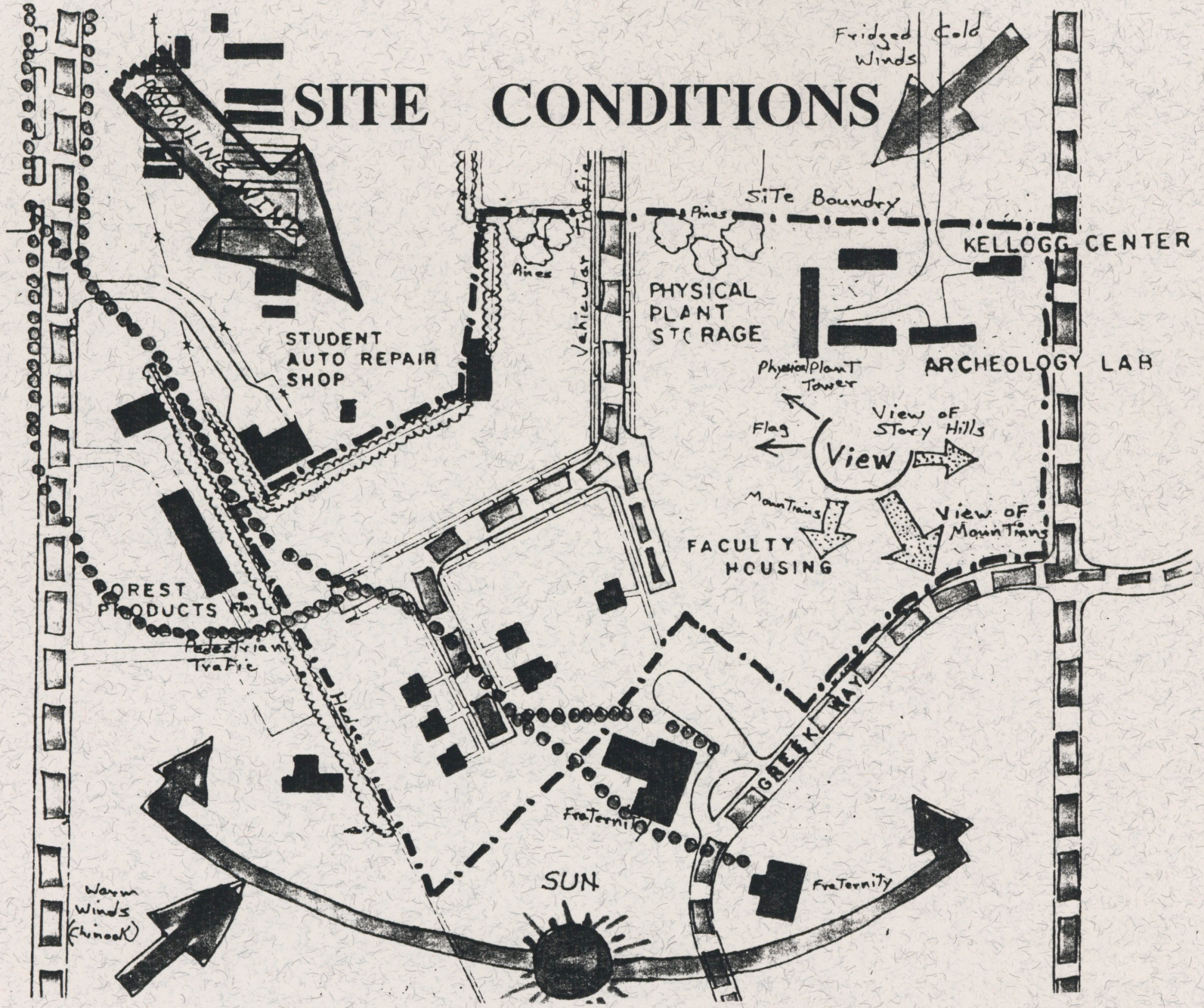


A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

SITE ANALYSIS



SITE ANALYSIS

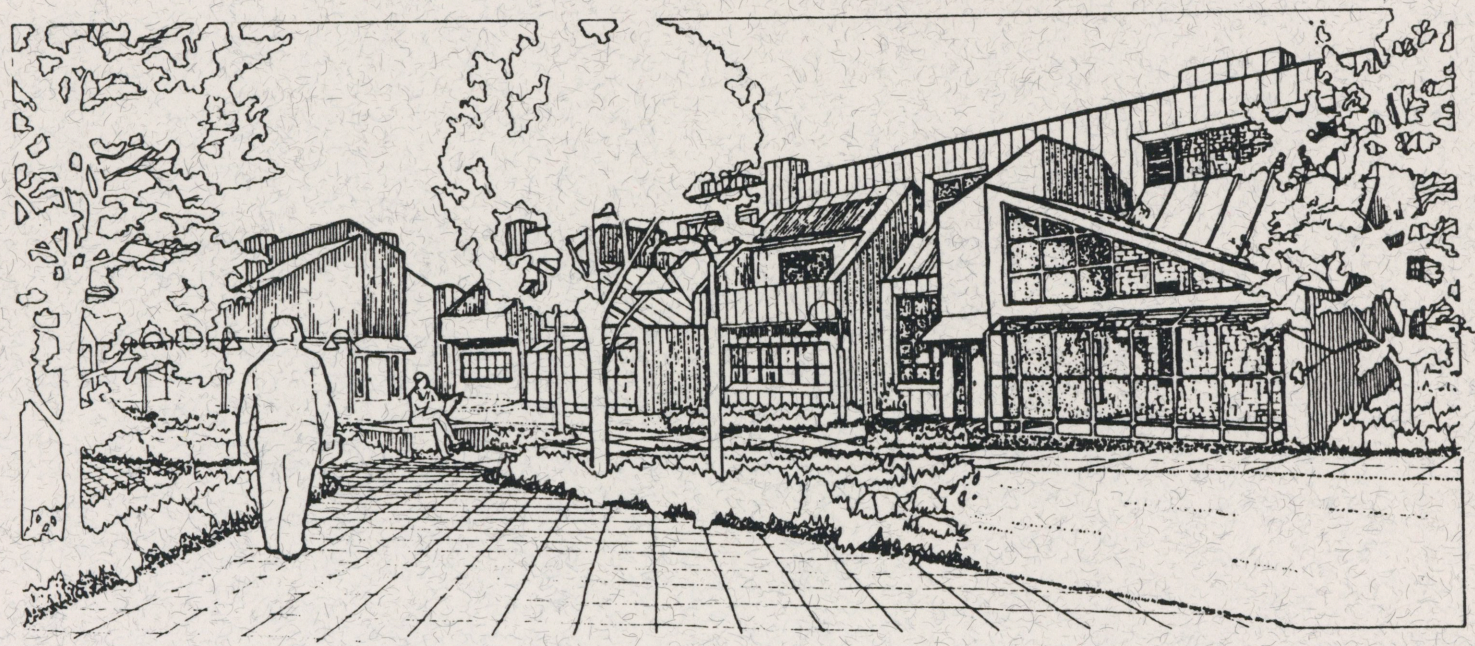
A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.

DOCUMENTATION

A FACULTY HOUSING PROJECT

MONTANA STATE UNIVERSITY BOZEMAN, MT.



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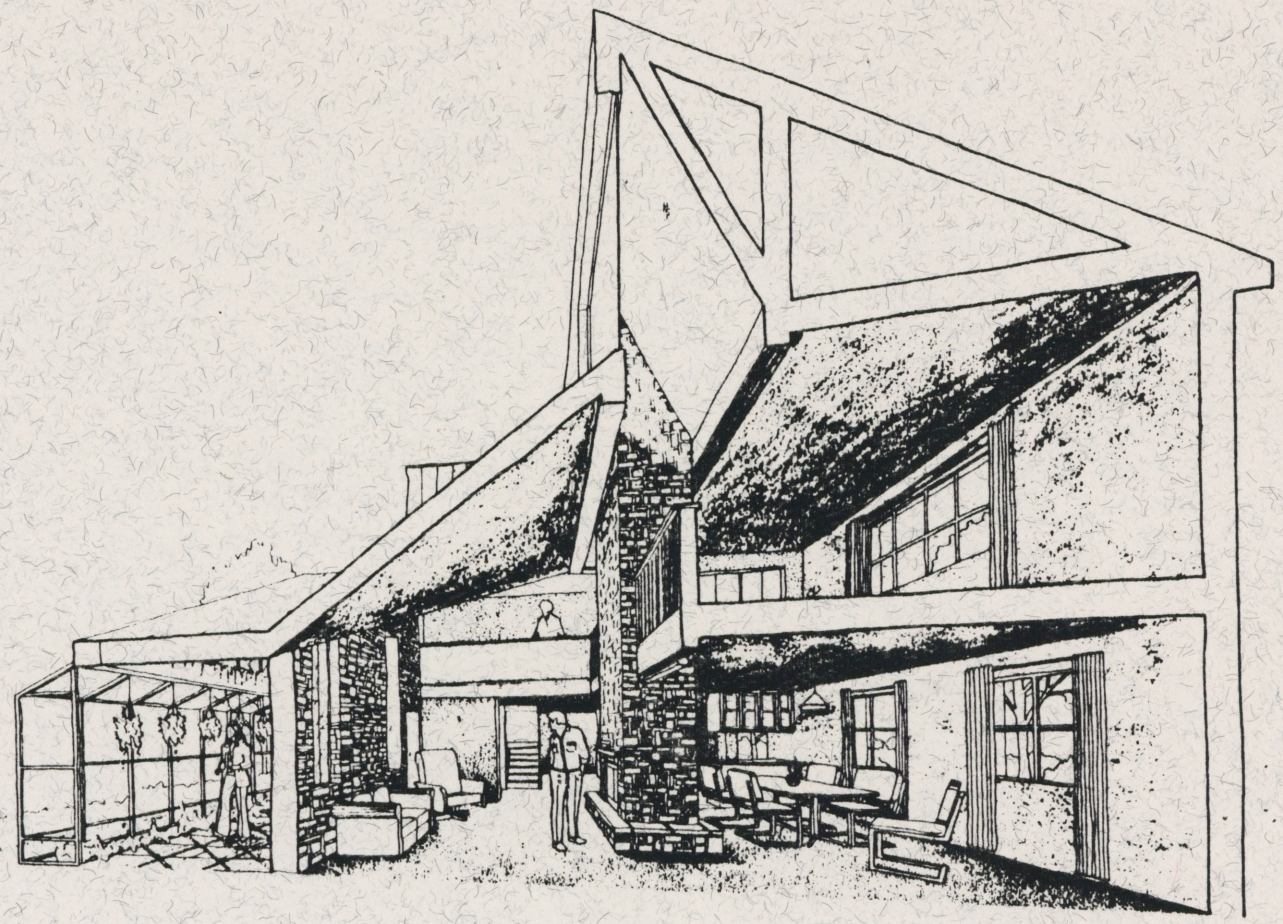
MONTANA STATE UNIVERSITY BOZEMAN, MT.

DOCUMENTATION



DOCUMENTATION

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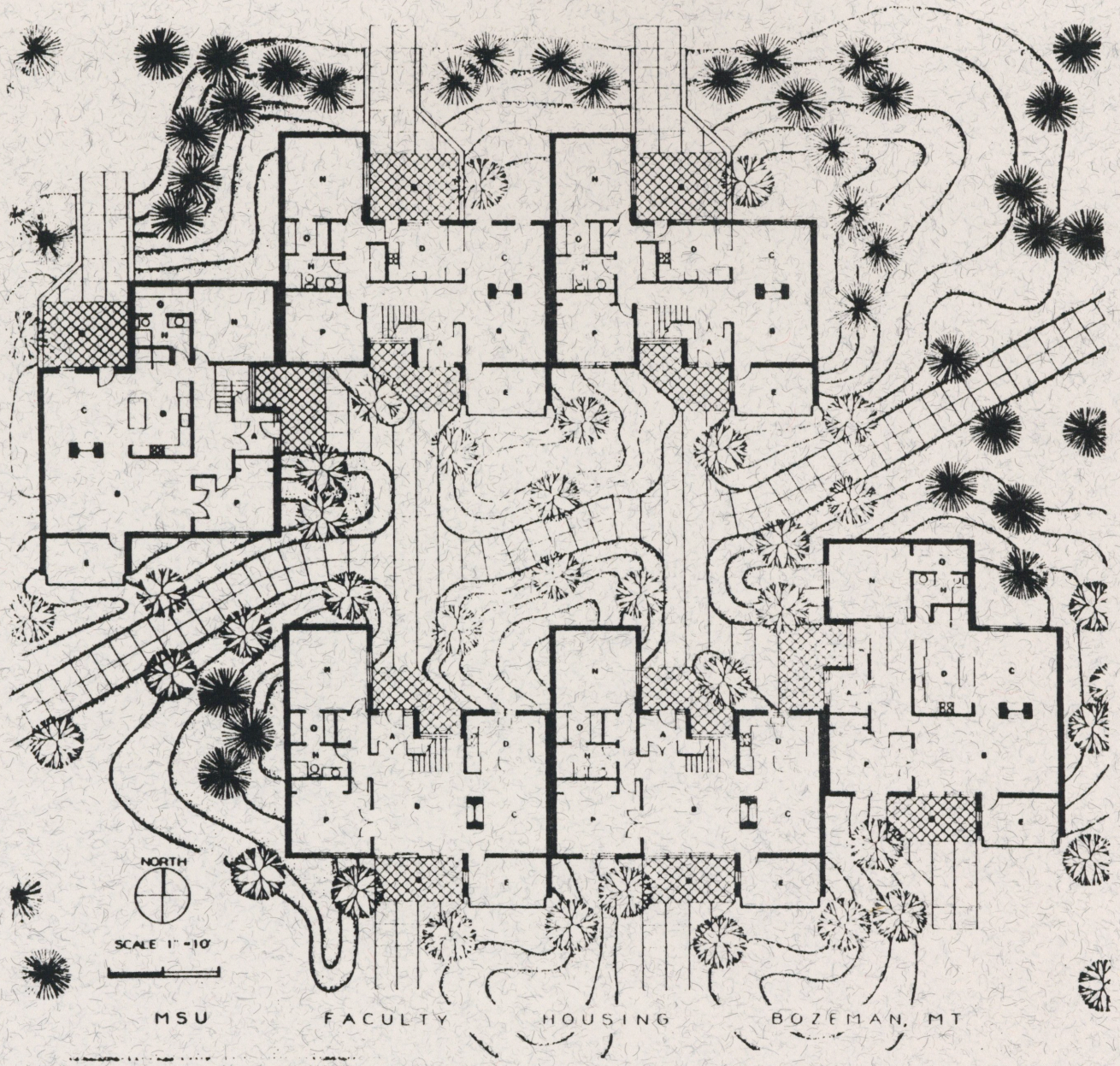

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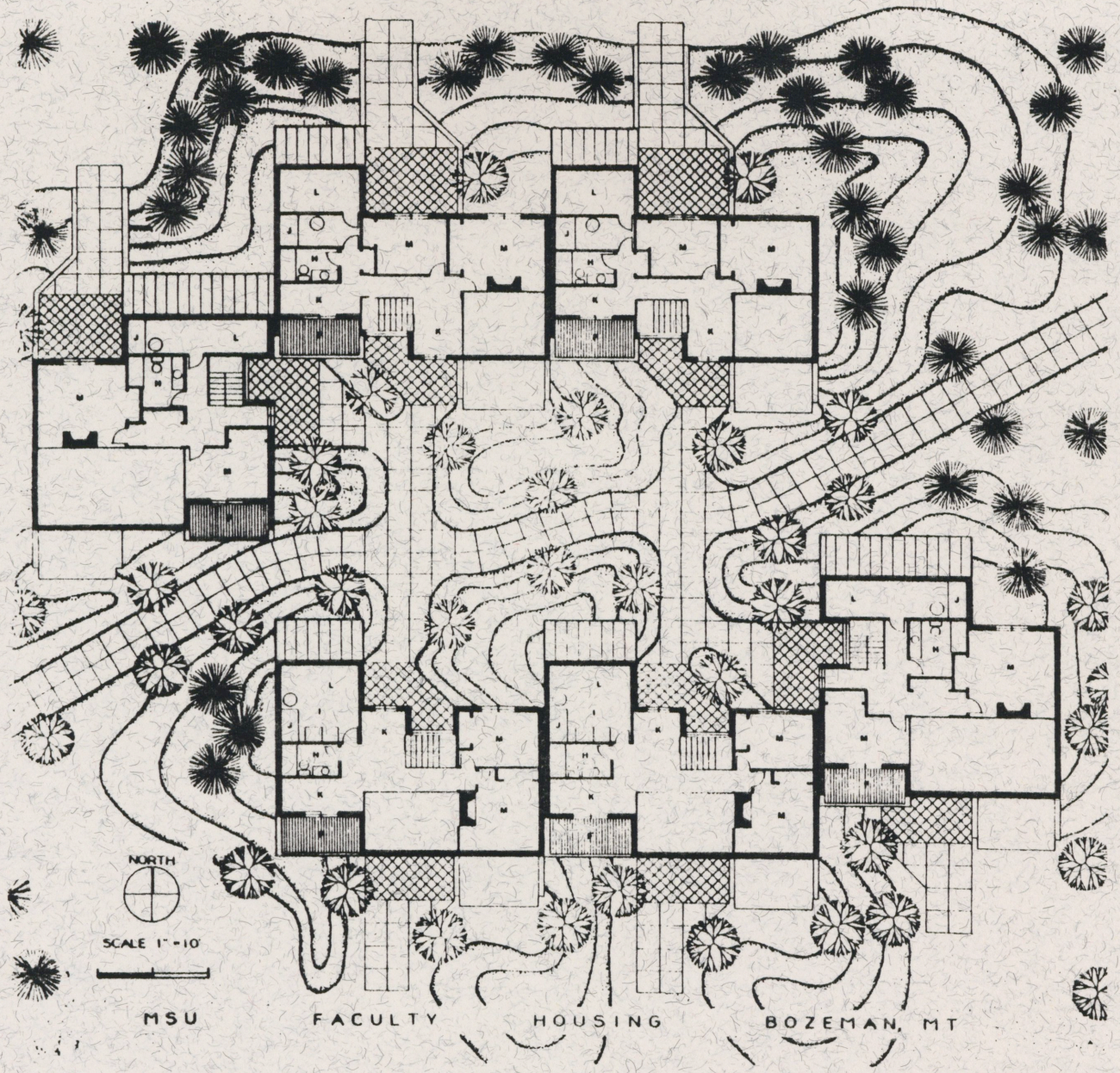

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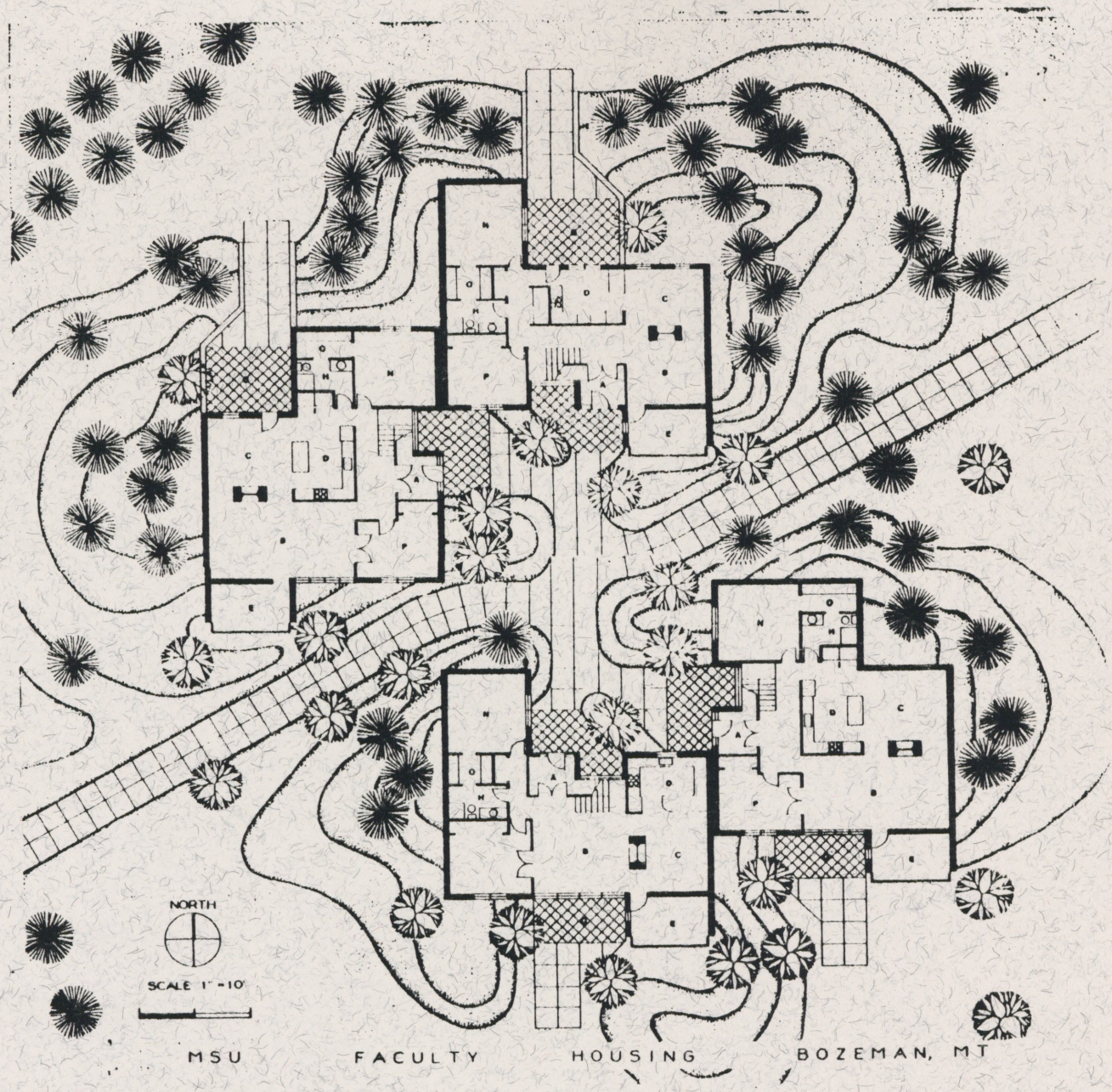

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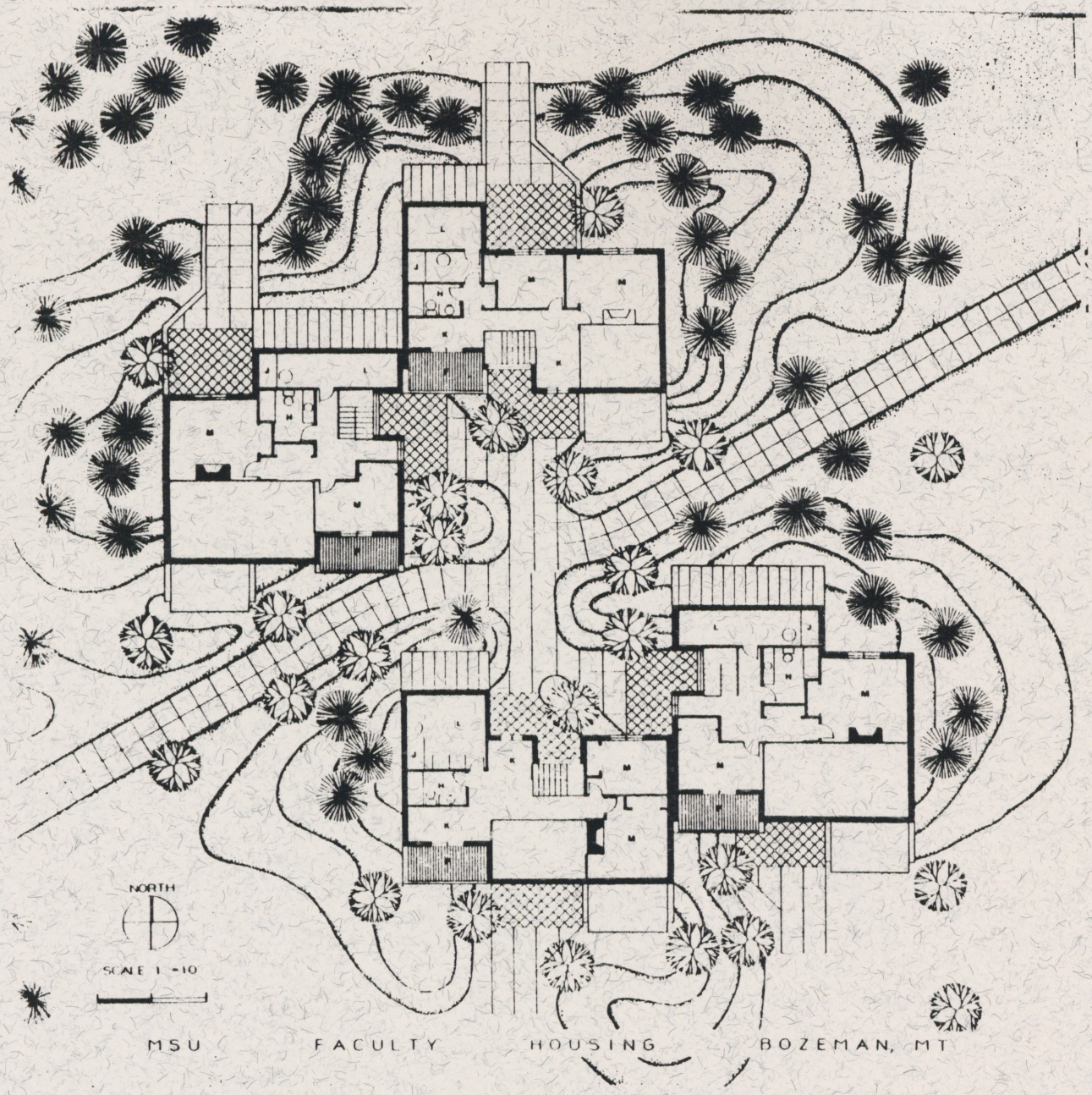

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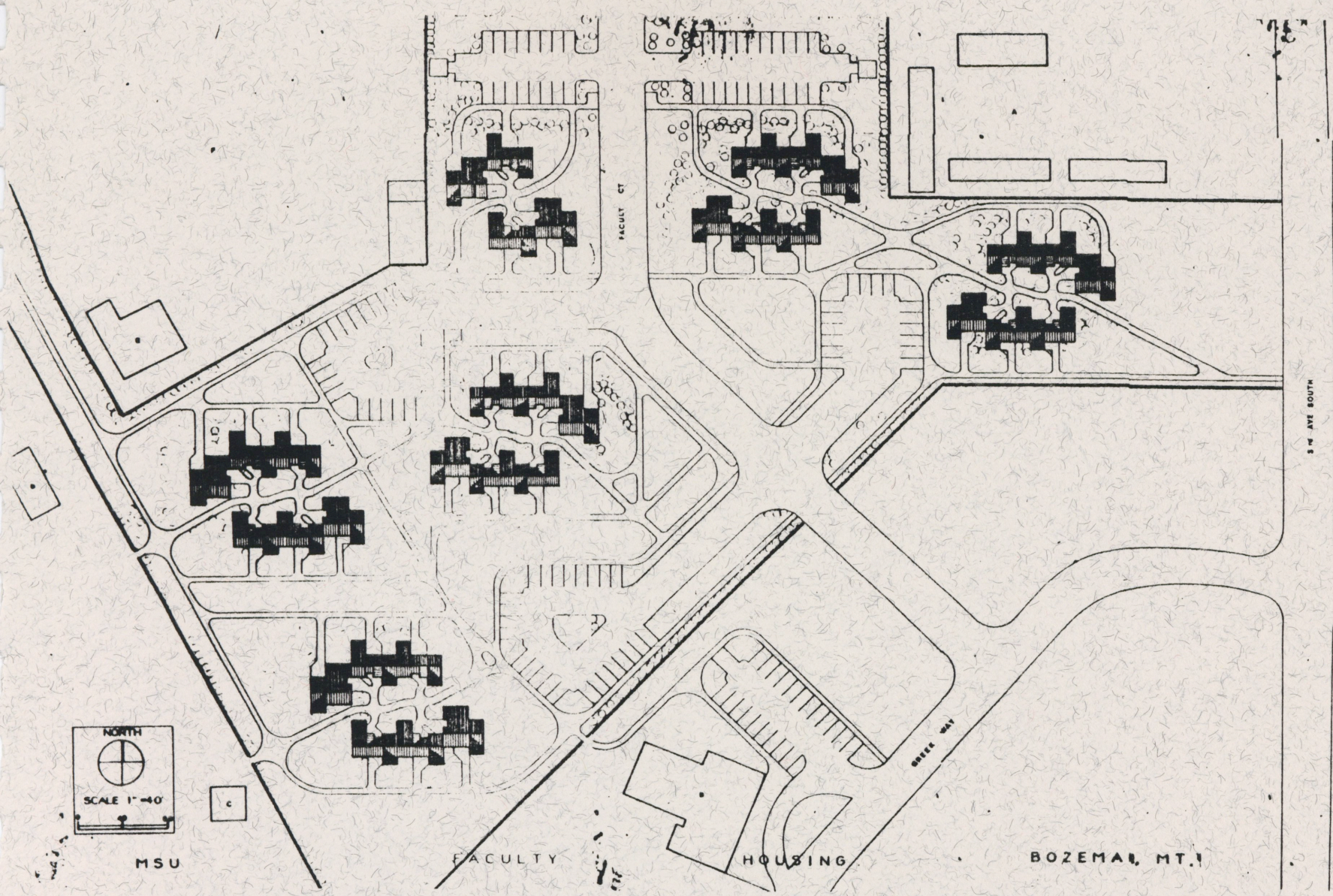

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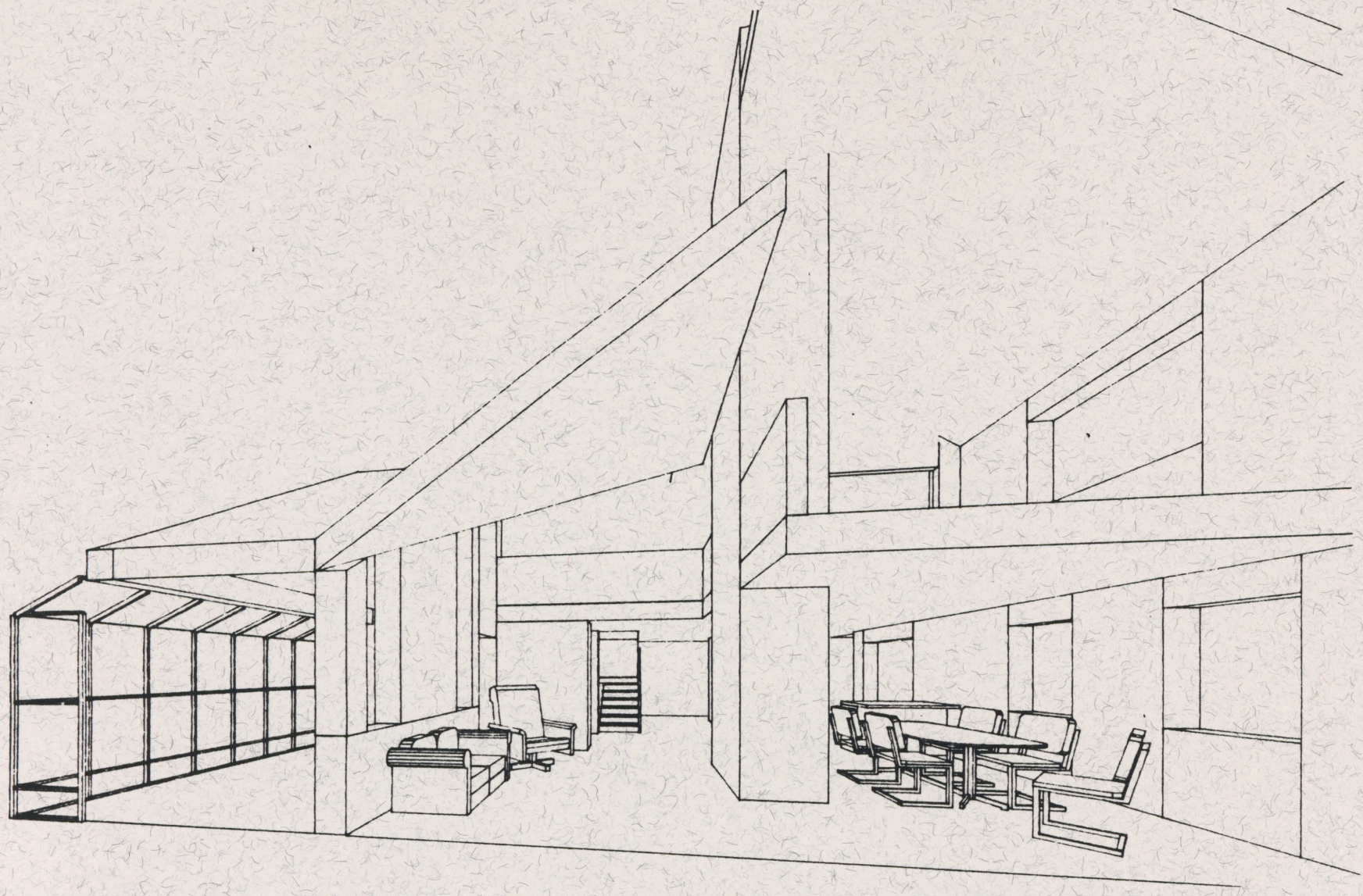

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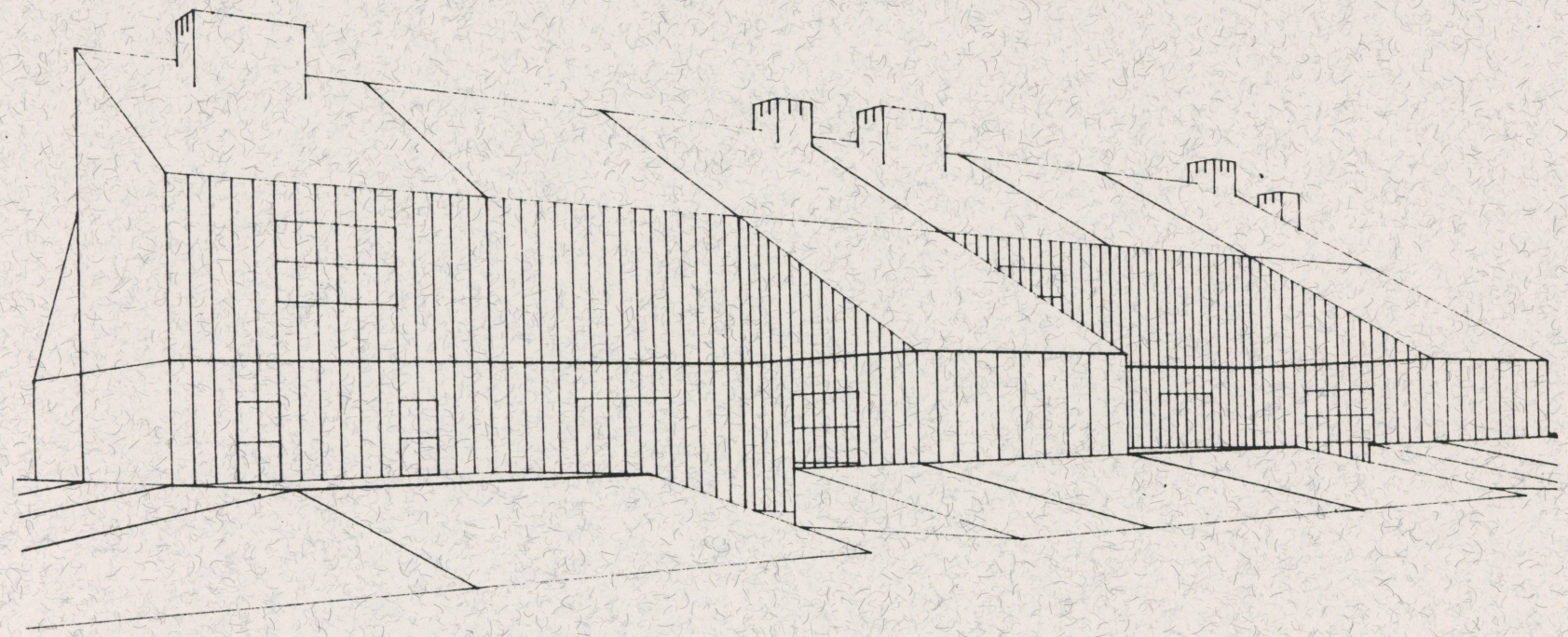

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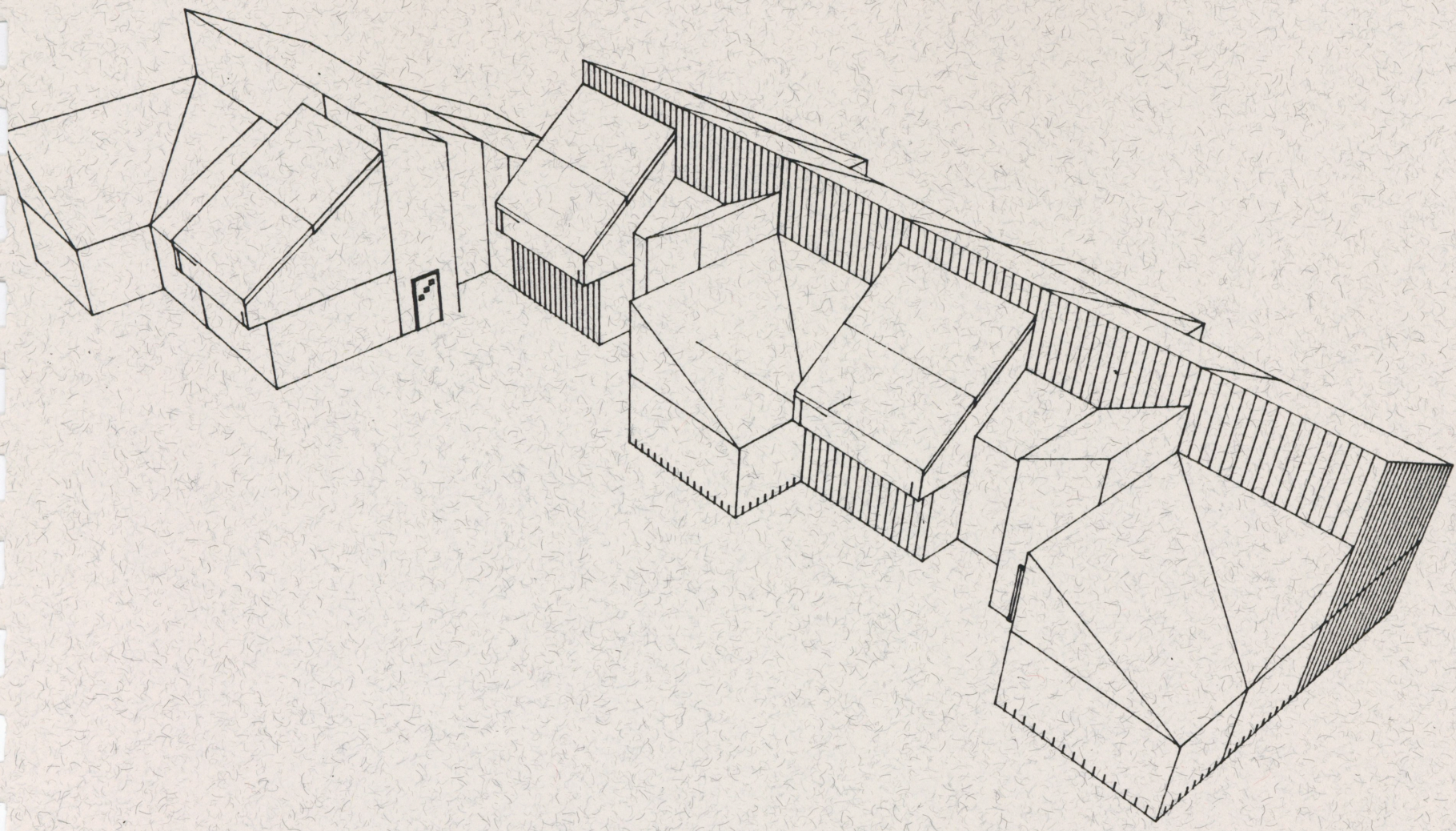

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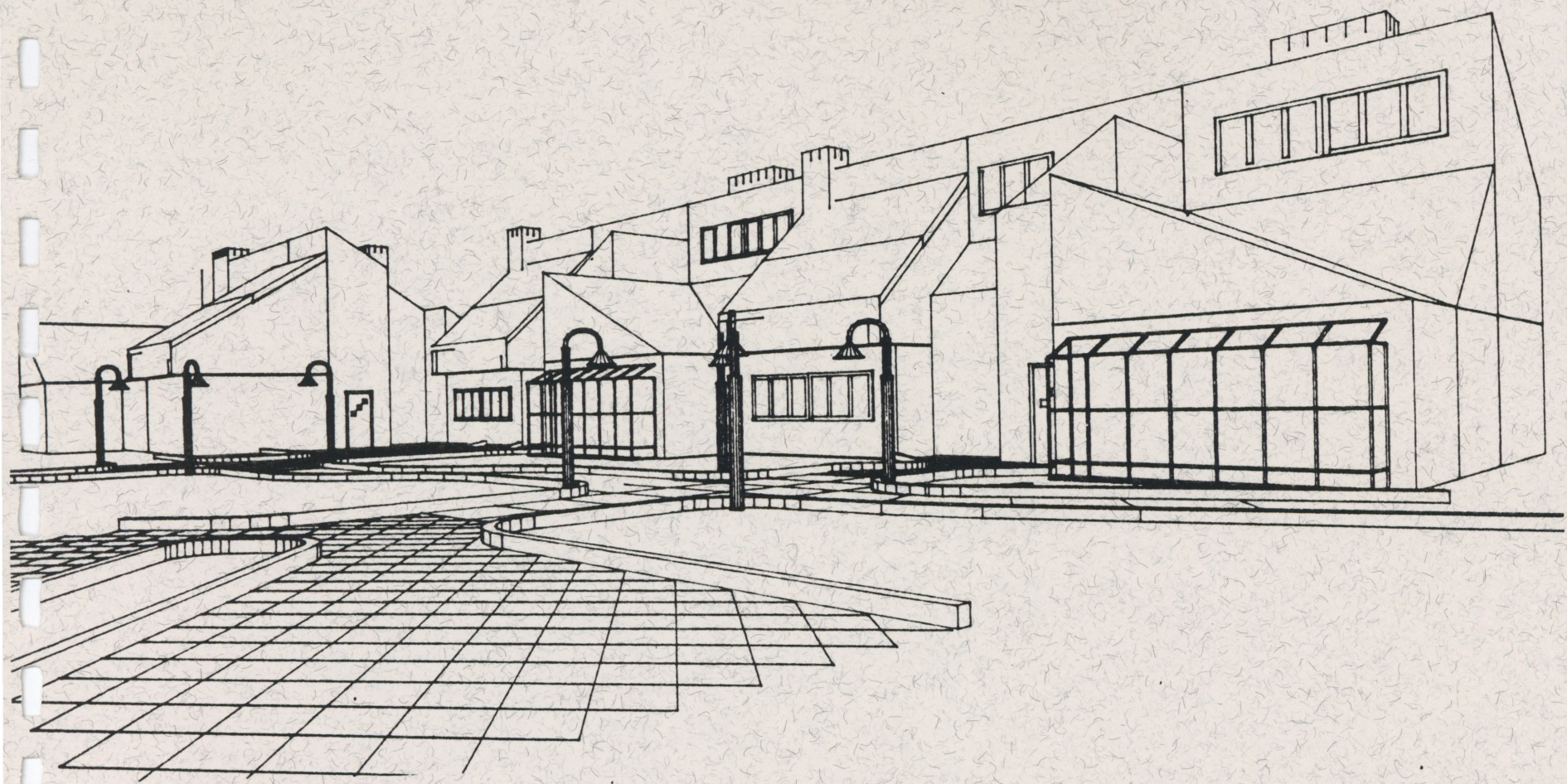

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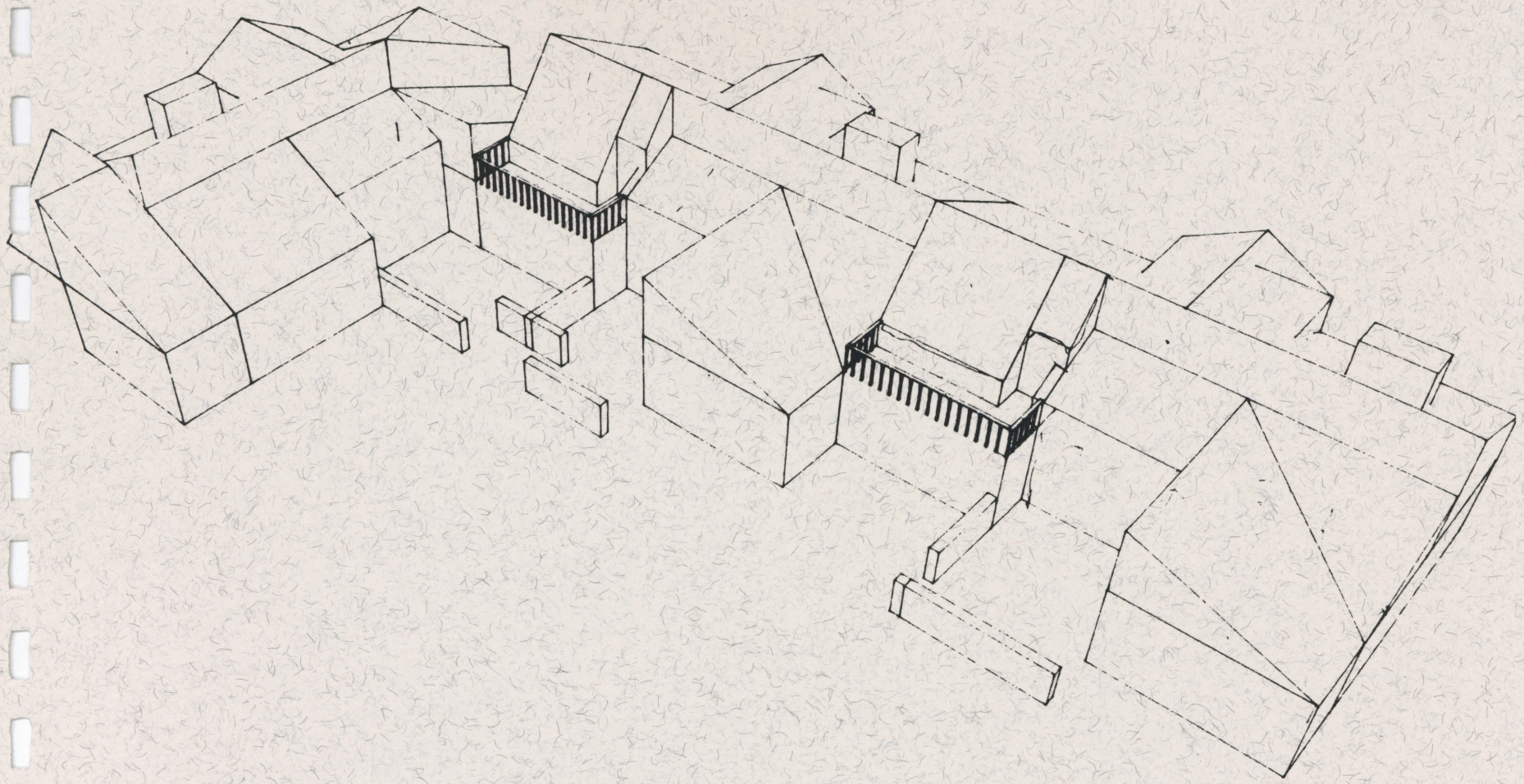

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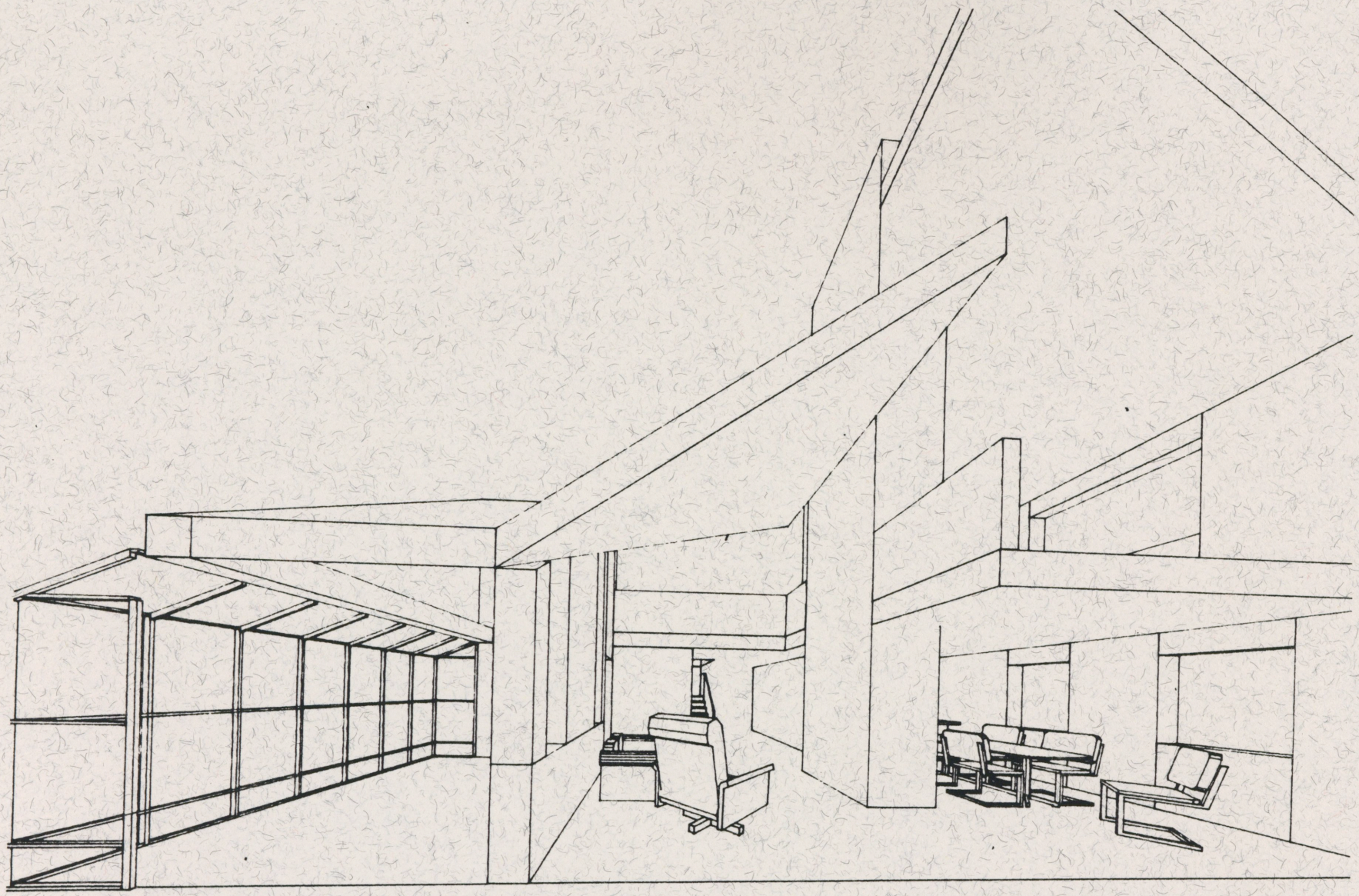

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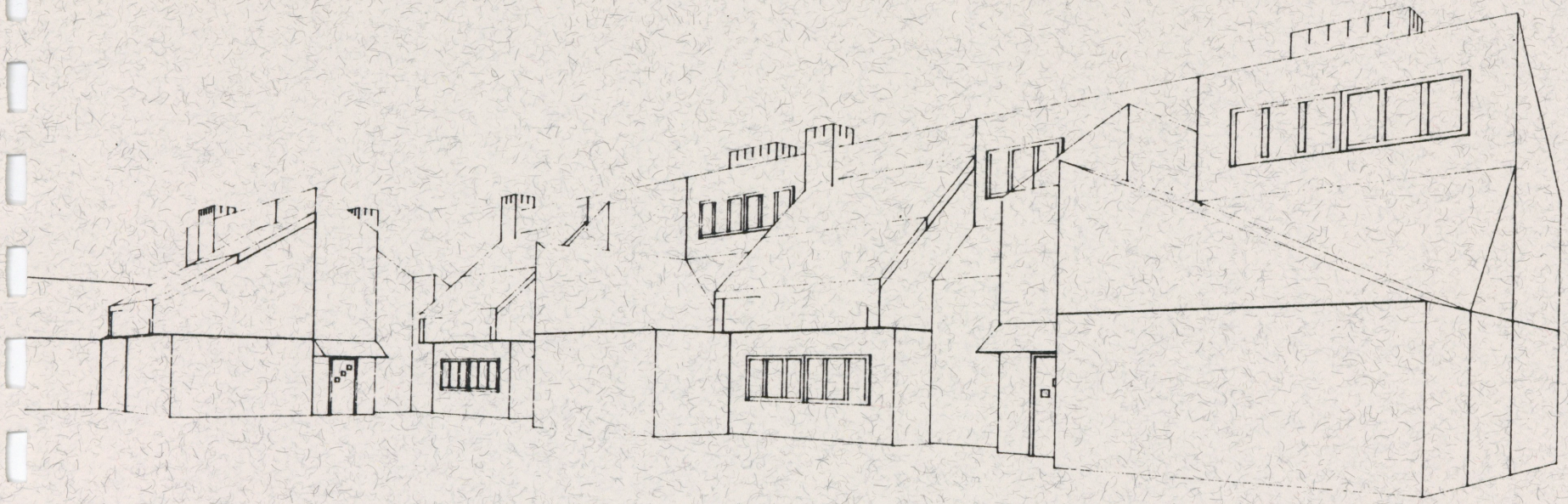

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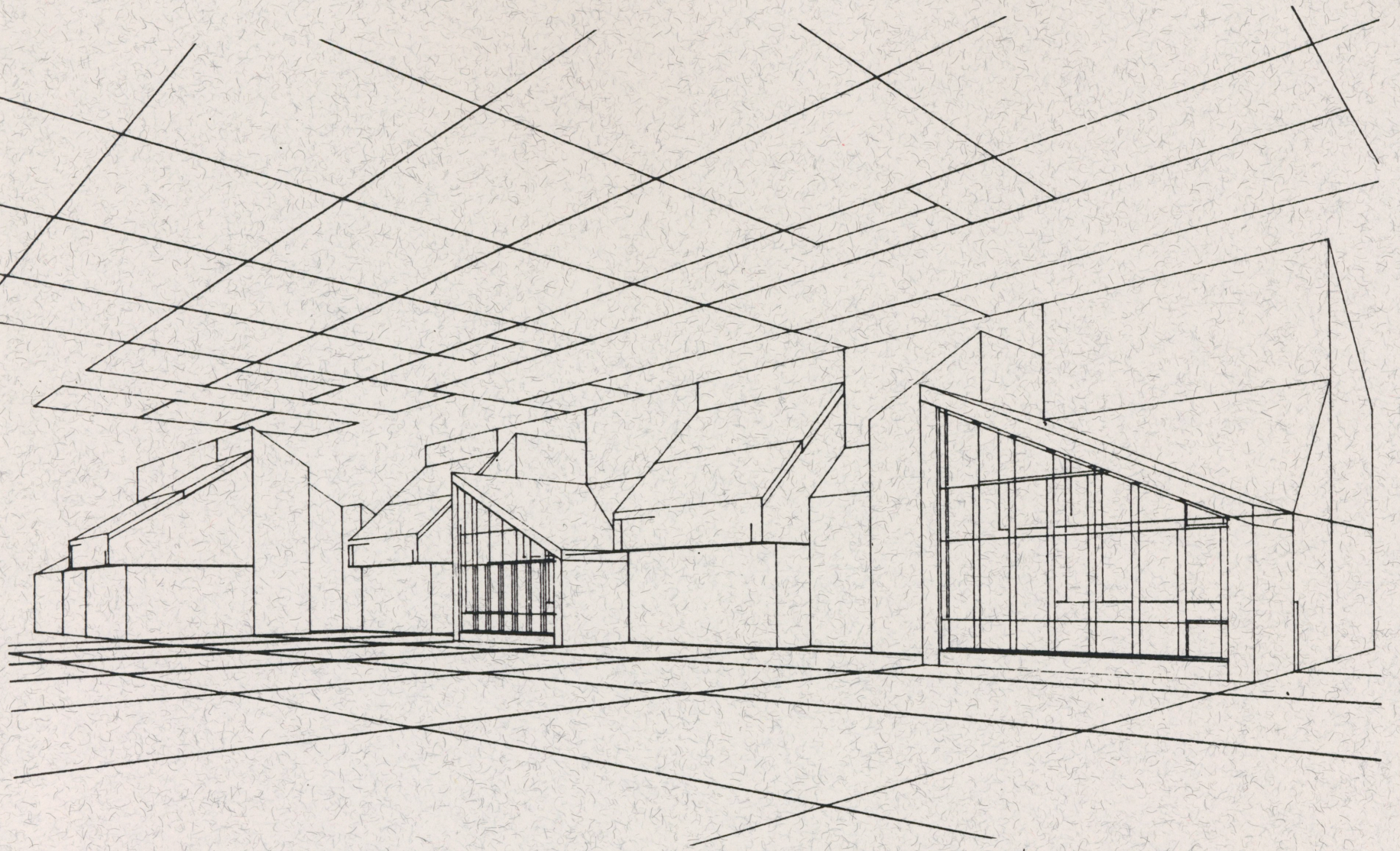

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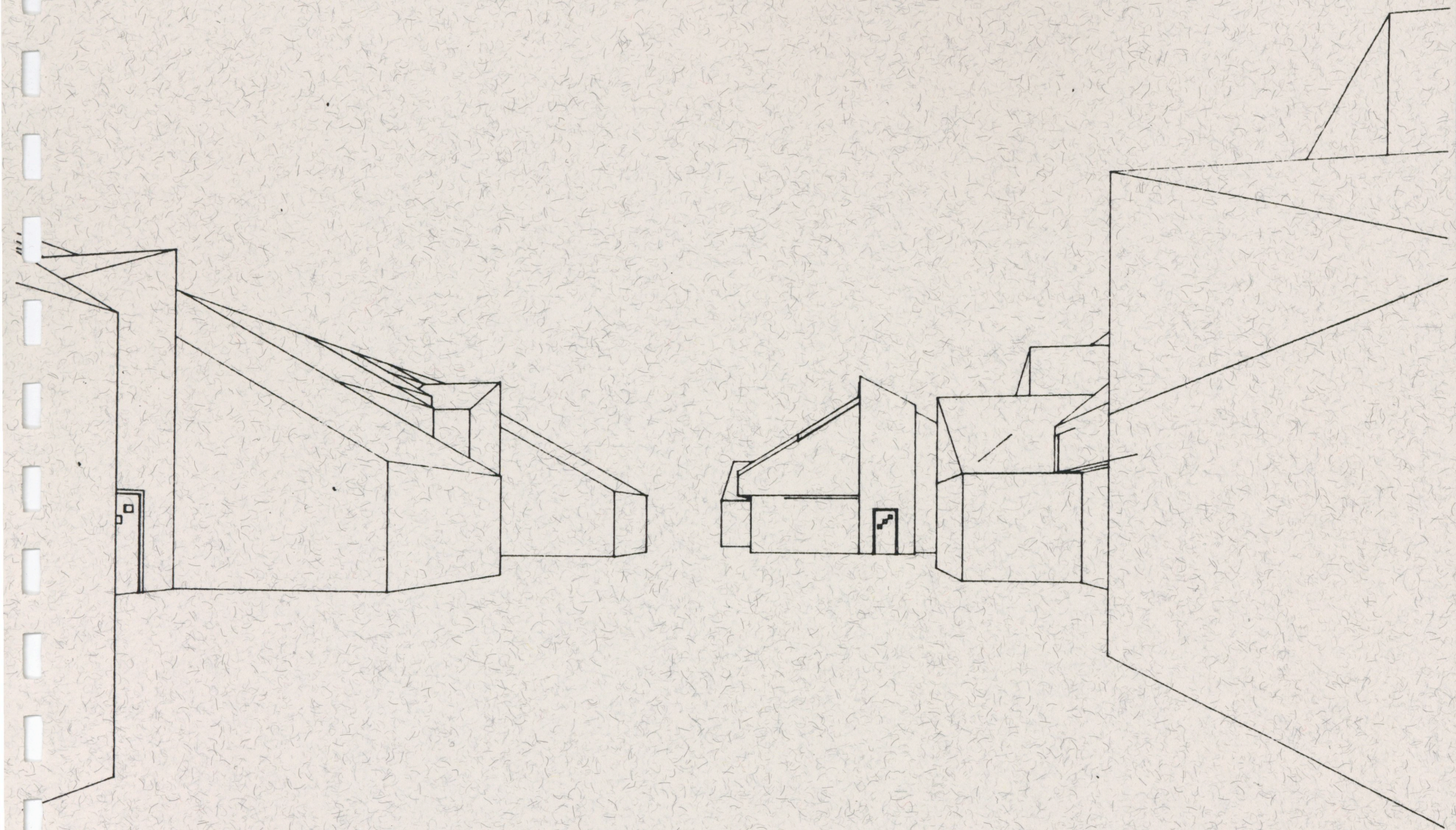

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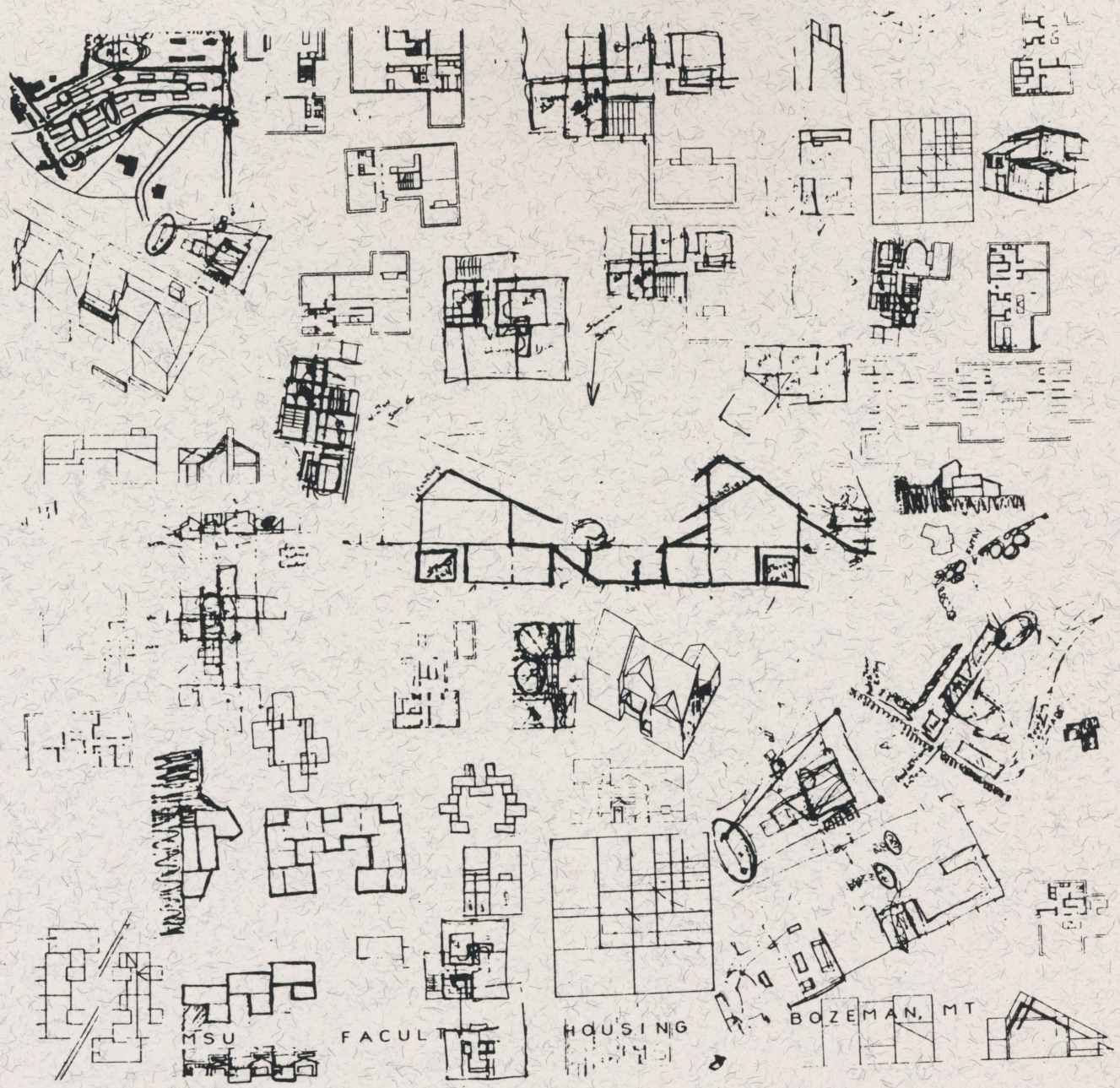

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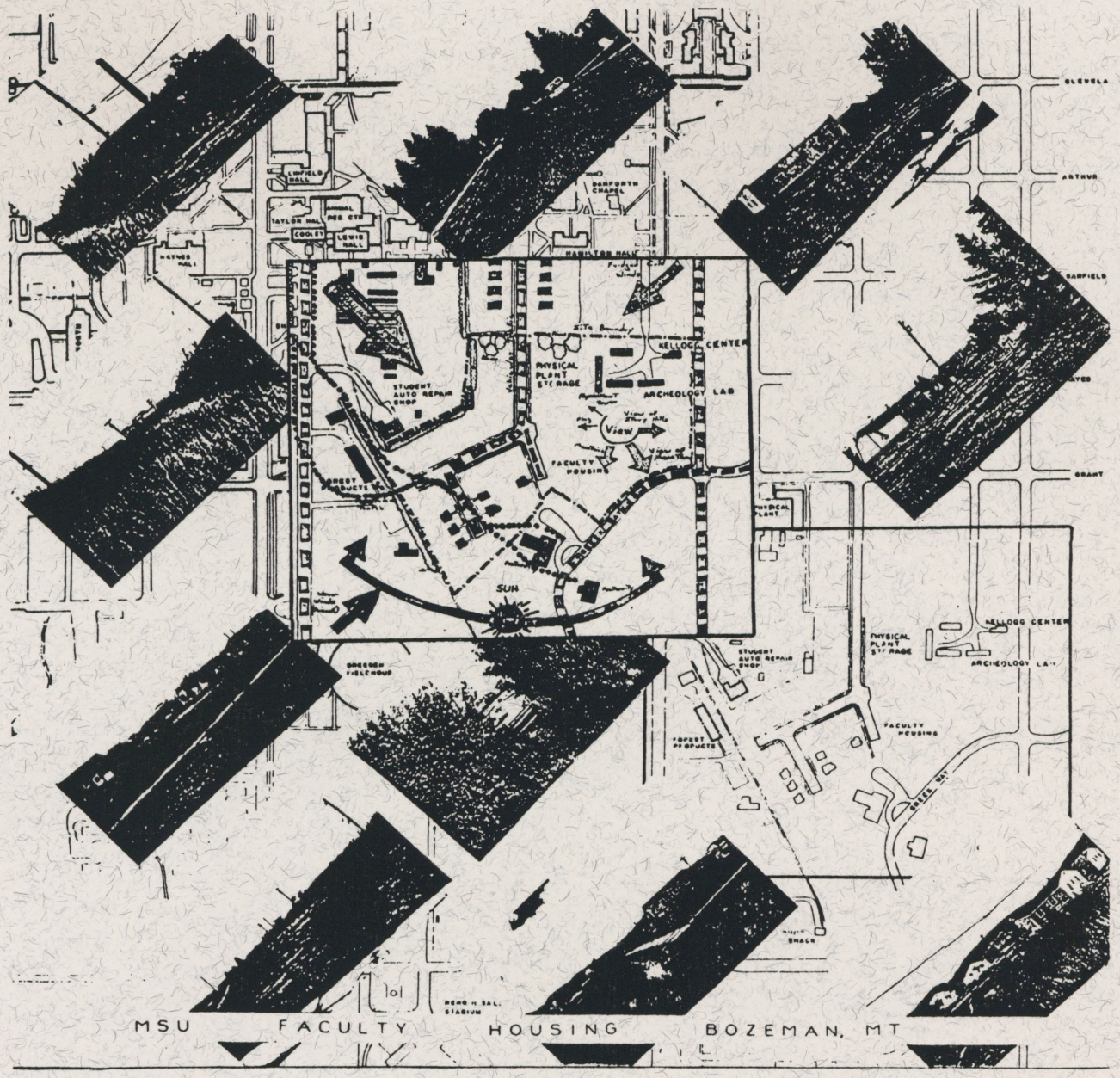

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PROJECT SUMMARY

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In summarizing the energy systems as they pertain to the faculty housing project, there are many systems available. I will discuss each of these systems and how they pertain to the project. Many energy systems should be a part of all architectural projects. The other energy systems have special requirements and need custom application. Available are two basic types of systems one is passive and the other is active.

Active systems are defined as needing outside energy for operation, such as fans and pumps. Energy systems produce a wide variety of energy, ranging from heat, gas, electric, and kinetic. The heat and gas can easily be stored for future use, but on the other hand, electricity and kinetic energy must be used at the time of production. Electricity can be sold to the utility companies, usually at a premium, and then purchased back when needed at the going rate. Benefits from producing electricity are; no pollution is given off to the atmosphere, and limited resources are not used in production. Because of the increasing problem of carbon pollution we must lean towards systems that are carbon free.

Lets take a look at several systems available to the faculty housing project. The first system that should be employed in all projects is passive heat gain systems like; green house, trombe wall, and direct gain. The second tactic that should always be considered is the use of landscaping to reduce wind and subsequent heat loses through convection. Other things that should be considered are adequate insulation, caulking, heat exchanger, and vapor barriers.

Photovoltaic can produce a good deal of the electric energy used in a home. In the faculty housing project photovoltaics were employed to reduce the energy demands of the project. The implementation of the photovoltaic had very little effect on the design of the project except that there was a need for a protected south facing slope.

The site has excellent possibilities for geothermal energy. The one problem of this system is there is no place for the waste warm water. In geothermal systems the waste water must be cooled and then disposed of without hurting the ecosystem of the watershed.

Wind power should be used at any site that county and state laws will permit. The expected life of this type of a wind power system is only about 20 years, and the return on the investment needs 20 years to break even. The environmental considerations should be enough to convince people of the use of wind power. The use of wind power generators will reduce our dependance on non renewable energy like fossil fuels.

Earth sheltered housing needs consideration on all projects because of the reduced temperature swings that can be obtained from this type of construction. If not complete burial of the structure then at least the use of earth berming. This can help reduce the convective heat losses.

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Biomass energy systems need rural settings and large scale production to be effective. Current zoning in the city of Bozeman, or for that mater most cites, will not allow the decomposition of waste materials within the cites limits. This type of system is best suited for farm operations.

Hydro-electric power plants require a good water source and plenty of "head" to be productive. If access to a water source like a river or stream then hydro-electric power generation would be a viable source.

Some systems that were not covered in this document are hydronics. This is a system of heating water or eutectic salts from the suns radiation in a closed system and then storing the heat energy for future use. The heat energy is then later pumped from storage cells through some type of radiant system in the space. The hydronics system was not used in this project mainly due to the large maintenance, and low efficiency of this type of system.

Another type of system that was not covered in this book was roof ponding. The main draw back to this system is the wide temperature swings in Bozeman, MT. This system is better suited for more moderate climates. Roof ponding can be used more effectively as a cooling system. Another problem with roof ponding is the efficiency of this kind of energy system.

Besides the energy systems in the project other considerations were made. Such things as density, arrangement, circulation, form, and quality of life were explored.

Several arrangements were explored in the faculty housing project. The best arrangement was found to be clustering of four to six units. This allowed increased security, and separation of pedestrian and automobile. Also this gave more room to public and private spaces outside of the buildings. Single organization of the units required to much land to be given up to vehicular circulation.

For the issue of identity of the individual person there was a need for individual units. The use of multi story units tends to give people a feeling of loss of their own identity. With units that have subtle differences, people can better maintain a sense of identity.

There are strong boundaries in the housing project. The perimeter of the site has excellent boundaries. This helps give a good sense of security for the community of the project. There are local boundaries created within each cluster of units this not only helps from an energy standpoint but adds to the sense of security.

The boundaries of the site and of each cluster of units will give a sense of community for not only the faculty housing project, but each cluster of units.

There are plenty of play areas for children. These areas have lawn, sidewalks, and small hills for children to play on. Children can play with out being around vehicles and can still be monitored by the parents.

There is good access to the university from the housing project, through paths that are not interrupted by vehicles. With the organization of paths there is good interaction of the residents through both forced and chance meetings.

The context of the project follows the Montana occurrence of the shed roof and salt box style of architecture. The use of the salt box style is a good regional response due to the energy saving aspects. These energy aspects are long sloping roofs for the wind to pass over and the steep south slope for energy heat gains.

The materials are both aestheticly complimentary, and at the same time have low maintenance. The use of metal roofing will reduce maintenance and produce a look of new construction. The use of wood siding is complementary to the context of Montana.

The noise of the site is reduced by localizing the services of groups of units, and the reduction vehicular traffic. Also the selection of a site that is remote from the activities of the campus will help in the prevention of noise.

The location of the faculty housing project is next to the physical plant and the maintenance centers. This will make servicing of the housing easer for campus staff.

This project has provided for three to four bedroom apartments. There are thirty four units with room for future expansion. The floor space of each unit is complementary to the standard that faculty will expect for their accommodations. The quality of life on the site will enhance the recruiting efforts of the University.

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GLOSSARY

absorbtance--the ratio of radiation absorbed by a surface and the total energy falling on the surface measured as a percentage.

active solar energy system--a system which requires the importation of energy from outside of the immediate environment: ie. energy for fans and pumps.

ambient temperature--surrounding temperature, as around a house.

angle of incidence--the angle that the suns rays make with a line perpendicular to a surface. The angle of incidence determines the percentage of direct sunshine intercepted by a surface.

auxiliary system--a supplementary heating system that provides heat to a space when the primary system can not do so.

azimuth-- the angular distance between true south and the point on the horizon directly below the sun.

bering angle-- see azimuth

berm--a man made mound or small hill of earth.

black body--a theoretically perfect absorber of incident radiation with also the highest possible emittance.

BTU (british thermal unit)--a unit used to measure a quantity of heat; the quantity of heat required to raise the temperature of one pound of water 1 degree F. 1 BTU = 252 calories. One BTU is approximately equal to burning one kitchen match.

calorie--a unit of heat (metric); the amount of energy equivalent to that needed to raise the temperature of one gram of water 1 degree C.

caulking--making an air tight seal by filling in cracks around windows and doors.

clerestory--a window that is placed vertically (or near vertical) in a wall above one's line of vision to provide natural light into a space.

collector, flat plate--an assembly containing a panel of metal or other suitable material, usually a flat black color on its sun side, that absorbs sunlight and converts it into heat.

collector, focusing--a collector that has a parabolic or other reflector which focuses sunlight onto a small area for collection.

collector, solar-- a device for capturing solar energy, ranging from ordinary windows to complex mechanical devices.

conductance (C)--the quantity of heat (BTU's) which will flow through on square foot of material in one hour, when there is one degree difference between both surfaces. Conductance values are given for a specific thickness of material.

conduction--the process by which heat energy is transferred through materials (solids, liquids, gasses) by molecular excitation of adjacent molecules.

conductivity (K)--the quantity of heat (BTU's) that will flow through one square foot of material, one inch thick, in one hour, when there is a temperature difference of 1 degree F between its surfaces.

convection--the transfer of heat between a moving fluid medium (liquid or gas) and a surface, or the transfer of heat within a fluid by movements within the fluid.

dead air space--a confined space of air. A dead air space tends to reduce both conduction and convection of heat.

degree-day (DD) cooling--see degree day for heating, except that the base temperature is established at 75 degrees F.

degree-day (DD) heating--an expression of a climatic heating requirement expressed by the difference in degree F below the average outdoor temperature for each day and an established indoor temperature of 65 degree F.

density--the mass of a substance which is expressed per cubic foot.

diffuse radiation--radiation that has traveled an indirect path from the sun because it has been scattered by particles in the atmosphere, such as air molecules, dust and water vapor. Indirect sunlight comes from the entire sky dome.

direct radiation--light that has traveled a straight path from the sun, as opposed to diffuse sky radiation.

efficiency--in solar applications, this measure pertains to the percentage of the solar energy incident on the face of the collector that is used for space heating.

emissivity--the property of emitting heat radiation; possessed by all materials to a varying extent. "Emittance" is the numerical value of this property, expressed a decimal fraction, for a particular material.

eltectic salts-- salts used for storing heat. At a given temperature, salts melt, absorbing large amounts of heat which will be released as the salts freeze. These temperatures rang from 80 to 120 degrees F.

glazing-- a covering of transparent or translucent material (glass or plastic) used for admitting light.

glazing, double-- a sandwich of two separated layers of glass or plastic enclosing air to create an insulating barrier.

greenhouse effect--the tendency of some transparent materials such as glass to transmit radiation of short wavelengths and block radiation of long wavelengths.

heat capacity (volumetric)--the number of BTU's a cubic foot of material can store with one degree increase in its temperature.

heat gain--an increase in the amount of heat contained in a space, resulting from direct solar radiation and the **heat given** off by people, lights, equipment, machinery and other sources.

heat loss--a decrease in the amount of heat contained in a space, resulting from heat flow through walls, windows, roof and other building envelope components.

infiltration--the uncontrolled movement of outdoor air into the interior of a building through cracks around windows and doors or in walls, roofs, and floors. This may work by cold air leaking in during the winter, or the reverse in the summer.

insolation--the total amount of solar radiation--direct, diffuse and reflected--striking a surface exposed to the sky. This incident solar radiation is measured in langleys per minute, or BTU's per square foot per hour or per day.

insulation--materials or systems used to prevent loss or gain of heat, usually employing very small dead air spaces to limit conduction and/or convection.

radiation--the direct transport of energy through space by means of electromagnetic waves.

radiation, infrared--electromagnetic radiation, whether from the sun or a warm body, that has wavelengths longer than the red end of the visible spectrum of light. We experience infrared radiation as heat; 49% of the radiation emitted by the sun is in the infrared band.

reflectance--the ratio or percentage of the amount of light reflected by a surface to the amount incident. the remainder that is not reflected is either absorbed by a material or transmitted through it. good light reflectors are not necessarily good heat reflectors.

resistance (R)--R is the reciprocal of conductivity or R=x/k. (x = equals the thickness of the material in inches.)

R-factor--a unit of thermal resistance used for comparing insulating values of different materials; the reciprocal of conductivity; The higher the R-factor of a material, the greater its insulating properties. See resistance(R).

solar altitude--the angle of the sun above the horizon measured in a vertical plane.

solar constant--the amount of radiation or heat energy that reaches the outside of the earths atmosphere.

solar radiation--electromagnetic radiation emitted by the sun.

solar window--openings that are designed or placed primarily to admit solar energy into a space.

specific heat (Cp)--the number of btu's required to raise the temperature of one pound of a substance 1 degree F in temperature.

thermal mass--the amount of potential heat storage capacity in a given assembly or system. Drum walls , concrete floors and adobe walls are examples of thermal mass.

time lag--the period of time between the absorbtion of solar radiation by a material and its release into a space. Time lag is an important consideration in sizing a thermal storage wall or Trombe wall.

transmittance--the ratio of the radiant energy transmitted through a substance to the total radiant energy **incident on its** surface.

U value (coefficient of heat transfer)--the number of BTU's that flow through one square foot of roof wall or floor, in one hour, when there is a 1 degree F. difference in temperature between the inside and outside air, under steady state conditions. the U value is reciprocal of the resistance or R-factor.

vapor barrier--a component of construction which is impervious to the flow of moisture and air and is used to prevent condensation in walls and other locations of insulation.

water wall--an interior wall of water-filled containers constituting a one-step heating system which combines collection and storage.

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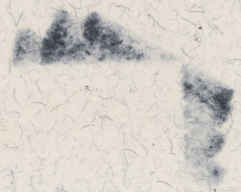

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