



Soils and associated natural resources as decision parameters in the regional planning process
by Bruce Frank Leeson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY in Crop and Soil Science
Montana State University
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Abstract:

The results of three and a half centuries of persistent wear and tear of their environment has become sorrowfully obvious to Americans only recently. Destruction of natural beauty, loss of human individuality, pollution of air, soil and water, and intensification of an inhospitable urban way of life have combined to create a compelling desire within the American population to "return to the land." Montana's bounty of open space, spectacular natural features, outdoor recreation opportunities and complacent way of life is and will attract a massive invasion of tourists, outdoor aficionados and recreation home and property seekers. That there is an urgency to possess knowledge facilitating efficient resource allocation and land use planning decisions is undeniable.

Interpretations of soil and associated natural resources for land use planning and development should have valuable application in locations where natural beauty is recognized to be an outstanding attribute. Gallatin County, Montana is experiencing extensive land use change which threatens to eventually desecrate the natural heritage which attracts so many immigrants. Formulation of research objectives therefore embodied collection, analysis and interpretation of soil and associated natural resource information pertinent to decision making in the regional planning process.

Soil and associated natural resource factors such as texture, slope and landscape position have been used to rate 39 per cent of the county as having slight, moderate or severe limitations for uses such as roads, septic tank drain fields, foundations and recreation areas. Individual, transparent, colour-coded soil limitation maps were prepared. These maps can be overlain to demonstrate a variety of locations with a wide range of soil and natural resource suitabilities or hazards for particular developments. The interpretations are useful for general planning purposes but do not provide sufficient information for on-site design and construction.

In order to achieve more meaningful predictions and interpretations, detailed soil and on-site investigations were performed for the purpose of facilitating enlarged appreciation for the hazards and costs of contradicting nature. Local development situations, both private and public, which incurred increased cost or reduced utility because of soil and associated resource constraints were examined and analyzed. A demonstration of real-life expenses resulting from poorly informed decision making lends credibility to the importance of using soil and associated resource interpretations as decision parameters in a planned growth undertaking. Such an approach has greater impact in efforts directed towards formulating a public philosophy that a "design with nature" is a rational basis for decision making in the regional planning process.

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ABSTRACT

The results of three and a half centuries of persistent wear and tear of their environment has become sorrowfully obvious to Americans only recently. Destruction of natural beauty, loss of human individuality, pollution of air, soil and water, and intensification of an inhospitable urban way of life have combined to create a compelling desire within the American population to "return to the land." Montana's bounty of open space, spectacular natural features, outdoor recreation opportunities and complacent way of life is and will attract a massive invasion of tourists, outdoor aficionados and recreation home and property seekers. That there is an urgency to possess knowledge facilitating efficient resource allocation and land use planning decisions is undeniable.

Interpretations of soil and associated natural resources for land use planning and development should have valuable application in locations where natural beauty is recognized to be an outstanding attribute. Gallatin County, Montana is experiencing extensive land use change which threatens to eventually desecrate the natural heritage which attracts so many immigrants. Formulation of research objectives therefore embodied collection, analysis and interpretation of soil and associated natural resource information pertinent to decision making in the regional planning process.

Soil and associated natural resource factors such as texture, slope and landscape position have been used to rate 39 per cent of the county as having slight, moderate or severe limitations for uses such as roads, septic tank drain fields, foundations and recreation areas. Individual, transparent, colour-coded soil limitation maps were prepared. These maps can be overlain to demonstrate a variety of locations with a wide range of soil and natural resource suitabilities or hazards for particular developments. The interpretations are useful for general planning purposes but do not provide sufficient information for on-site design and construction.

In order to achieve more meaningful predictions and interpretations, detailed soil and on-site investigations were performed for the purpose of facilitating enlarged appreciation for the hazards and costs of contradicting nature. Local development situations, both private and public, which incurred increased cost or reduced utility because of soil and associated resource constraints were examined and analyzed. A demonstration of real-life expenses resulting from poorly informed decision making lends credibility to the importance of using soil and associated resource interpretations as decision parameters in a planned growth undertaking. Such an approach has greater impact in efforts directed towards formulating a public philosophy that a "design with nature" is a rational basis for decision making in the regional planning process.

I. INTRODUCTION

Throughout the length and the breadth of the North American continent participants in the "good life" of the Western World are becoming increasingly disturbed by the pressing paradoxes of our modern age:

- that as societies grow richer, their environments grow poorer;
- that as the array of obtainable objects expands, the quality of life declines;
- that as we acquire more leisure to enjoy our surroundings, we find less around us to enjoy.

Man and nature are twin conspirators in the perennial revolution which shapes and reshapes the face of the earth. Land use and resource allocation problems have become acute and dramatic since technology and death control have facilitated an explosive growth of population which is amazingly adept at manipulating many of the natural processes of the planet. Man has always competed with other forms of life for space and has always been victorious by ingenious application of his superior intelligence. This same mental efficiency which sadly lacks the instincts of those creatures which we have dominated has bred man's greatest competitor--himself. Residences, business, industry, transport, waste disposal, water supply, agriculture, forestry, military and a host of intangibles are increasingly intensifying the legitimacy of their claim for space and resources. The outcome in many urban-suburban-industrial areas has been outright

disaster and it is the fear of a similar pattern of unplanned and destructive development in unspoiled places which has inspired the recent phenomenon of emotional concern for the environment and how we use it. Because "homo sapiens" are organisms and as such require specialized environments, it is reasonable to think that man cannot continue to indefinitely survive on this planet without utilizing its natural resources prudently. We are greatly impressed by our capability to change our environment, but we should be no less impressed by species vulnerability inherent in our inability to organically adapt to the many hostile environments which we create at a rate far in excess of evolutionary possibilities, e.g., radioactive contamination or biological warfare.

We cannot expect to restore the entire past nor to preserve all the present for future generations. The American pioneer, always short on capital but long on ingenuity and relentless ambition approached the utilization of the assumed limitless resources of the continent with reckless abandon. To be economically and physically secure, he altered nature and his relationship to nature with steadfast determination and undiminished perseverance. The American society is one which has grown very quickly and with unequalled prosperity. We became progressively more production conscious and aware of the profit margin than we were of the effects we were creating in our environment. The reciprocal of the Gross National Product has become a measure of

the state of health of our natural environmental heritage. Never before has a nation of people enjoyed greater luxury, mobility, expendible income and leisure time than do Americans at present. But paradoxically, never before have population centralization, hostile surroundings, degraded environment and threatened depletion of essential resources been so effective in diminishing the potential enjoyment of our affluence. As fast as horizons have been opened to our consciousness they have receded from our grasp. The ideas of desire and forces of ability when frustrated by the realities of nonattainment and disillusion in search of a "better way of life" have acted in concert to bring regional and resources planning into the forefront of American life.

The region may range from a small sleepy crossroads to a huge sprawling megalopolis such as "Bos-Wash." The resource may be as small as a single tree or as large as the total water supply of a continent. Transcending the whole spectrum of the nation's concern however, is a sense of urgency which inspires action to engage in regional resources planning. President Nixon in transferring the First Annual Report of the Council on Environmental Quality to Congress (11) emphasized this point by stating:

"Throughout the nation there is a critical need for more effective land use planning, for better controls over the use of the land and the living systems that depend on it. Throughout our history, our greatest resource has been the land--forests and plains, mountains and marshlands,

rivers and lakes. Our land has sustained us. It has given us a love of freedom, a sense of security, and courage to test the unknown.

"We have treated our land as if it were a limitless resource. Traditionally, Americans have felt that what they do with their own land is their own business. This attitude has been a natural outgrowth of the pioneer spirit. Today we are coming to realize that our land is finite, while our population is growing. The uses to which our generation puts the land can either expand or severely limit the choices our children will have. The time has come when we must accept the idea that none of us has a right to abuse the land, and that on the contrary society as a whole has a legitimate interest in proper land use. There is a national interest in effective land use planning all across the nation.

"I believe that the problems of urbanization which I have described, of resource management, and of land and water use generally can only be met by comprehensive approaches which take into account the evident range of social, economic and ecological concerns. I believe we must work toward development of a National Land Use Policy to be carried out by an effective partnership of federal, state and local governments together, and, where appropriate, with new institutional arrangements (11).

H. Wayne Pritchard, Director of the Soil Conservation Society of America; when addressing the September 1971 Annual Meeting of the Western States Soil Conservation Committees, Commissions and Boards referred to President Nixon's statements when he (Pritchard) proposed,

"that we have now reached the point in our development as a nation where we may be ready to adopt a land use policy for federal, state and local governments that will be recognized as policy.....

"To adopt such a policy it will mean we are ready to accept the concept that legal ownership of land does not necessarily carry with it the right for the owner to use the land as he may desire--use determination will in some manner, become a responsibility of public policy.

"To adopt such a policy it means that well defined characteristics of land types which will aid public decision as to use must be established--and this is where disciplines related to land use will need to consider their recommendations.

"Thus I await with interest the developments that will take place in your respective states in the next few years.....If you do not provide the leadership in this matter of land use policy for your state and community--there will be others less qualified who will do so (57).

Montanans', although they pay for the high quality of their environmental fortune with low per capita income, relative lack of cultural opportunity and high unemployment are very cognizant of their outdoor heritage. In fact it seems likely that most people living in Montana are well aware of the trade-offs involved and are here because of the ready availability of truly unique outdoor opportunities. This is substantiated in part in reasons given by persons who make financial sacrifices to move to Montana (72). Montana, relative to many other states is the enviable possessor of natural beauty, cleanliness and space, and constitutes in the eyes of many people a virtual unscratched gem within the 48 contiguous states. It is this very feature which makes Montana so attractive to "out-of-staters" who are disillusioned with city life elsewhere.

About 73 per cent of the nation's 203.2 million people live in urban areas (10) (79). This constitutes a very small part of the land surface of the United States--about 1 per cent. Montana represents a temporary escape or permanent retreat opportunity for many of these

149 million people who by anxiously searching for a better way of life may constitute a rural migration of modern day land boom proportions. In contrast to the urban migration, this rural influx will not be one for economic reasons but rather will be for rejuvenation of peace of mind. Nevertheless, the demand for and potential change in use of Montana lands will be dramatic.

Day to day indications of the growing interest in land purchase and development activities are relatively subtle in Montana and are analogous to the tip of the real estate iceberg. High visibility is accorded to the Big Sky Recreational Complex in Gallatin Canyon, but while emotions run high on the desirability of this activity, other industrious and similarly imaginative individuals are quietly engaged in land acquisition with development intentions varying from a few acres to thousands of acres. Whether Montana is or is not technically prepared to accommodate this growth and the inevitable land use changes will be evident in the cost and quality of the developments. There is merit, therefore in a research project with philosophical objectives of facilitating better informed decision making in resource development and regional planning. Consequently, the specific objectives of the efforts reported in this thesis have been, i. to obtain resource information pertinent to decision making in the regional planning process, ii. to interpret this information and present these predictions in an easily understood context, and iii. to support the predictive land use

ratings with detailed technical and economic investigations. If anyone is unconvinced that preparation is necessary it would be appropriate for him to become informed of the nature and magnitude of national trends because herein lies a major part of the reason for Montana's future growth potential.

National Trends Pertinent to Resource Use

There is little doubt that presently prevailing demographic, economic and technical trends in the United States will have a profound effect on natural resource use.

The 1970 census shows 203.2 million people in the United States and although crude birth rate has declined by one-fourth since 1960, there undoubtedly will be more Americans in the future than there are today. Present predictions that there will be somewhat fewer than 300 million persons in the United States in 2000 A.D. are lower than Pickard's 1967 prediction of 314 million by 2000 A.D. The previously mentioned decline in the birth rate during the 60's has prompted this re-evaluation (10). Nevertheless, a population increase of about 30 per cent combined with an assumed steady, or more likely accelerated rate of increase in standard of living intimates a tremendous demand for land, resources and space.

Urbanization is more likely to continue increased expansion rate rather than decrease. While the 1970 national population increased by

13.3 per cent, or 23,888,751 people since 1960, the urban population increased by 24,056,180 people or 19.2 per cent (79). This obviously indicates that a greater number of people took up permanent urban residence during the 1960-1970 decade than what was added to the whole country. While thousands of words and statements have been expounded upon the negative effects of crowded and unhealthful urban environments, the fact remains that more and more people are being attracted to the city. As affluence, mobility and leisure time increase however, an "escape syndrome" becomes established and subsequently much effort, thought and expense is devoted by restless, disillusioned people to getting away to a place in the country (53). The escape route frequently takes the form of a vacation, an outdoor recreational activity and/or the purchase of country property and a second home. An increasing population with more spare cash and more spare time to spend it has set off a recreational explosion of astounding proportions.

Americans spent 58.3 billion dollars in pursuit of leisure activities in 1965, 71 billion dollars in 1967 and 82.6 billion dollars in 1969. It is estimated that 105 billion dollars will be spent for leisure purposes in 1972. This exceeds the outlay for construction of new homes, surpasses the total of corporate profits and is far larger than the aggregate income of U.S. farmers (15). A breakdown of the expected 1972 expenditure is shown in Table 1.

Recreation--sports equipment and activities.....	\$50 billion
Vacations and recreation trips in U.S.	\$40 billion
Travel abroad.....	\$ 7.5 billion
Vacation lands and lots.....	\$ 5.5 billion
Second homes.....	\$ 2 billion

Table 1 Expected Expenditure For Leisure Activities by Americans
in 1972.

Dollar total in sales of leisure equipment have increased about 52 per cent for the past five years. One reason for the upsurge in equipment buying is the increasing desire to "get back to nature." Right now there are four million camping vehicles in the United States. The recreational-vehicle industry estimates that sales this year will exceed 1.8 billion dollars and predicts that there will be 7.5 million camping vehicles in the United States by 1978. The National Parks Service expects a record 212 million visits to its areas this year. A survey by the Department of the Interior shows that 75 per cent of the United States population from age nine upward is involved in some form of outdoor recreation.

Although picnicking and swimming are still two of the most popular activities, the leisure boom is characterized by two modern-day trends which are opening up vast new areas of space requiring activities--use of recreation vehicles and winter sports. Trail bikes, minibikes,

4 WD's, ATV's and dune buggies have come into common usage throughout the nation and their sheer numbers and potential land damage have necessitated use regulation action (48) (68). Snowmobiles however are probably of greater significance in regard to space requirements and the change in attitude towards winter recreation in that areas previously inaccessible due to deep snow have become winter playgrounds. Ironically however, these machines have inspired the wrath and opposition of "anti-vehicle" sportsmen. The interest and engagement in hiking, backpacking, crosscountry skiing and snowshoeing has experienced unprecedented popularity. Increased participation in and expenditures for bicycling, downhill skiing, golf and camping all add up to an overwhelming demand for recognition of a legitimate claim for space and resources of appropriate quality for the proposed activity.

In the ultimate attempt to enjoy "the best of all possible worlds," many urban dwellers are purchasing vacation properties and constructing second homes which serve as a recreational retreat. There are approximately two million American families who own a second home and it is projected that by 1980 a total of six million vacation, or second homes will be owned by American families (66). The complementary but much larger companion of the second home movement is the vacation land and rural lot market. According to the American Land Development Association, a trade group, there are now 9,000 vacation-land-development firms in the United States (15). The American Land Development

Association estimates that the industry sold 650,000 lots valued at 5.5 billion dollars in 1971. The average lot sold for nine thousand dollars and was one-quarter acre in size.

As surely as increased affluence and spare time have permitted indulgence in outdoor recreational pursuits, increased mobility has facilitated it. The American Automobile Association estimates that vacationing motorists will drive 300 billion miles and spend 40 billion dollars getting to and from vacation areas in 1972 (15). The speed and efficiency of air travel has cut distance and travel time considerations drastically as can be demonstrated by Figure 1, pg. 12. The ready availability of rental cars, rental campers, package vacations and guided vacation tours makes virtually any part of the American outdoors accessible to anyone able to afford it. Many major resorts advertise the fallacy of their remoteness by the short-time air flights required to travel from almost anywhere in the nation to their doorsteps, e.g., 300 minutes from anywhere in the United States to Big Sky (6).

That these national trends characterized by a "return to the land" will have a profound effect on the Western United States is a near certainty. This is particularly evident in the Rocky Mountains and is reflected in the dramatic increase in recreational visitor use and in land dealing activities. Problems of recreational overkill and environmental destruction are frequently demonstrated at prominent out-

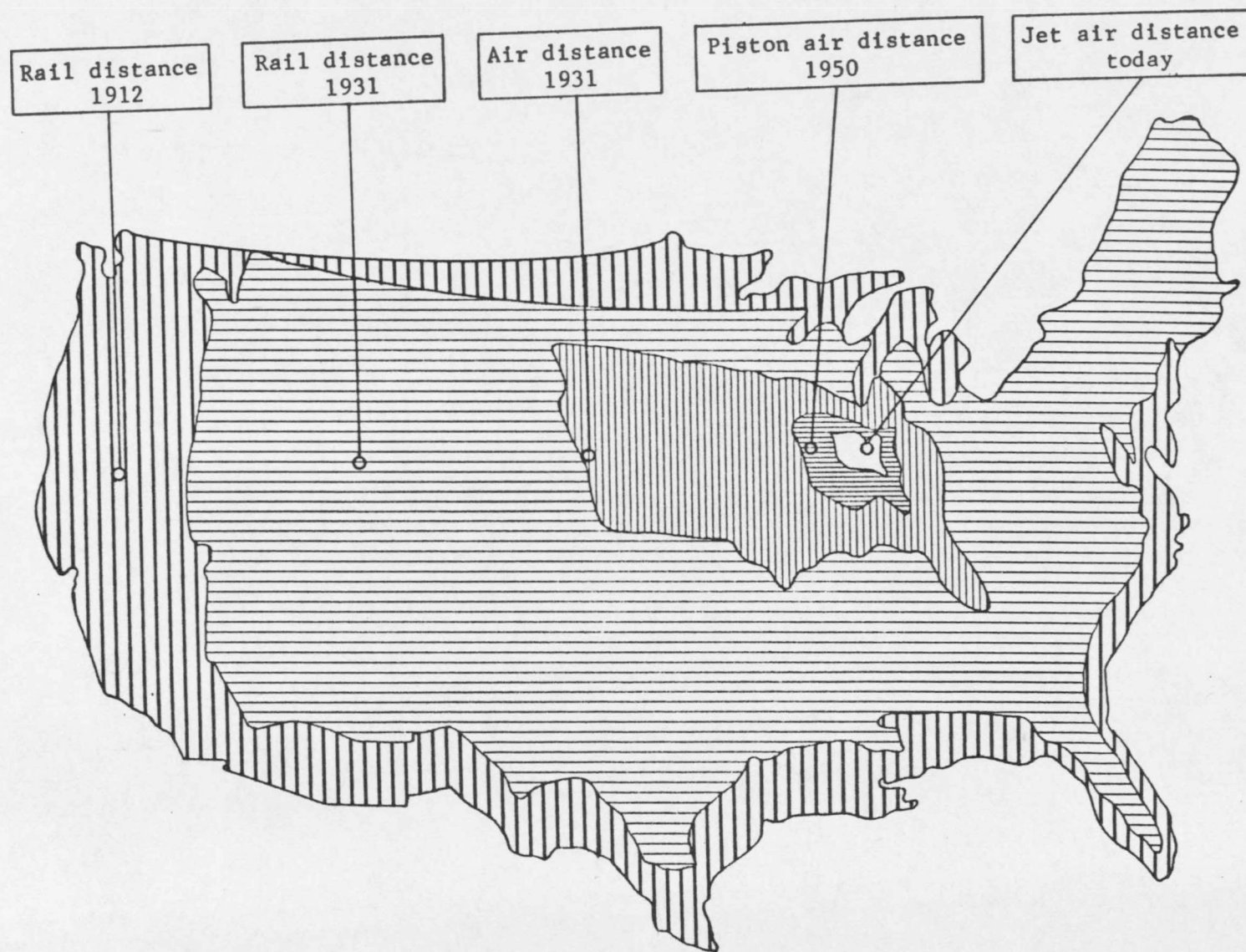


Figure 1. Contraction Of The Nation Since 1912 Due To Transportation Technology.

door attractions such as Yosemite National Park in California. Residential development has severely infringed upon the quality of an outdoor experience in places such as the Wasatch Front in Utah, the Front Range in Colorado and the Lake Tahoe Basin in California and Nevada. Throughout the length and the breadth of the Rocky Mountains, property for recreational and residential purposes is for sale. Similar forces, although less obvious but potentially no less effective are present in Montana.

The Rush to Stake Claims on Western Land

In the vast tracts of comparatively empty territory stretching from the Mexican border north to Montana and Idaho, speculators, developers and individuals are buying scenic mountain areas, river bank property, farmland, old mining claims and desolate desert wasteland with eager abandon. Some are fast-buck operators, others are major developers and holding companies making long term investments, and the vast majority of those who end up owning the land are retirement and recreation land seekers. The land acquisition procedure varies from the high-powered, slick approach of companies such as described by Pew in his article "Peddling the Great West," (54) to whole families heading for the hills with all their possessions, not unlike the pioneers, who not knowing where they were going or what they would do when they got there but knowing only that they were grateful to get

away from that which they left behind.

A Lovel, Wyoming real estate agent describing inquiries from all over the country says, "They all have one thing in common--desire for some land where they can get away from traffic jams, pollution, crime and suburban problems.....What they see may be alkali and sagebrush to us, but if it has a stream and a view of the mountains, it is paradise to them and we have a buyer" (46). In Montana, a Missoula real estate agent says that most buyers "think the ideal place is about ten acres with a stream that runs the year around. They want some trees and enough meadows for a couple of horses" (46). Desolate, dry, rocky land in Texas sells as fast as ranches can be subdivided into tracts of six, forty or more acre parcels. "The buyers want something with size, remoteness and wilderness. They are city people who don't want to go from a highly developed urban atmosphere to the same sort of thing in the country" (46). As ready and as capable as people are to buy western property there are others who are more anxious and more willing to sell it to them.

A perusal of enticing real estate advertisements which appear in many popular monthly magazines reveals the nature of the western land market.

"Own a piece of the famous Coeur d'Alene country.....
Top recreation and investment opportunities in the choice
location of the beautiful Pacific Northwest. All acreages
on or near lakes or streams. Secluded, yet near towns and
commercial transportation.....Low down payment and excellent

terms." Mattawa Land and Cattle Company, Incorporated (50).

"Own your own piece of land in the great Pacific Northwest.....Start buying your own recreation land now in the primitive areas of Montana, Idaho, Washington.....Irreplaceable natural land for enjoyment now, for retirement or investment." Reforestation Incorporated (51).

"Lewis and Clark Found It--Now You Can Own It. We're in the best position to offer you prime land in the heart of Lewis and Clark country. Much of it still looks the way it did in 1805 and we know where it is. Many five to forty acre tracts for recreation, retirement, investment in Idaho, Montana and Washington.....Low down payment. Easy terms." Western Highlands, Inc. (37).

"For investment, retirement, vacation or recreation--or for full time southern Colorado living four seasons of the year, the Sangre de Cristo Ranches are your chance of a lifetime to acquire a sizeable piece of choice property on exceptionally easy terms." Sangre de Cristo Ranches Incorporated (64).

These are typical excerpts from four of 33 separate real estate advertisements which appear in the April, 1972 issue of Sports Afield magazine (70). Eleven of the advertisements described available property in or closely adjacent to the Rocky Mountains and all extolled the virtues of the high quality outdoor opportunities. While the appeal of all western land agents is to the ready availability of unmatched outdoor recreational experiences--hunting, fishing, riding, hiking--the investment aspect of acquiring western land is carefully emphasized. It is very aptly paraphrased by one advertiser:

"The high profit potential of land investment in America's great Southwest makes this a wonderful opportunity to obtain desirable, low cost property in this high growth area. Because real estate tends to increase in value during periods of rising prices, your ranch may be considered an excellent safeguard against inflation" (64).

Many of the original investors in western lands were attempting to take advantage of the agricultural tax shelter by purchasing farmlands, investing heavily in improvements, operating at an apparent loss and subtracting such investments and losses from their income taxes. Since the passage of the Tax Reform Act of 1969, this practice has dwindled but the purchase of large blocks of land by corporations has probably increased. Although the return on investment in a ranch operation is only two or three per cent, the four to six per cent annual appreciation in value added to the initial return on the investment (profit) makes ranching a reasonable investment (63). When the efficiency of economy of scale, opportunity for vertical integration, and benefits from lower rates of capital gains taxation combine to increase the potential profit margin, the trend toward corporate ownership and operation of huge ranches is easily comprehended.

Investors, individuals and corporations alike, when seeking a secure, long term growth investment in the face of inflation, uncertain stock markets, labour and union problems, and sky-rocketing manufacturing costs, are turning to land purchases. It is not surprising then for many of the "big names" in the corporate world to move into the land business as a diversified sideline to their operation. A sampling of such companies are General Motors, Ford, Chrysler, Standard Oil Company of California, Aluminum Company of America, U.S. Steel, Bethlehem Steel, American Broadcasting (47). Companies which are actively

engaged in land development enterprises are Forbes Magazine, Northwest Orient Airlines, Chrysler Realty Corp., Northern Pacific Railway, Montana Power Company, Continental Oil Company, Meridian Investing and Development Company and the General Electric Pension Fund (64) (5) (26). In addition, paper and timber companies such as Boise Cascade, Weyerhaeuser, St. Regis, Scott, International Paper and others who own large tracts of land to assure their supplies of raw materials are frequently mentioned in activities capitalizing on the recreation population boom in natural resource developments (35) (8). Major railroads such as Union Pacific and Burlington Northern are big holders of land and real estate, much of it in the West. Burlington Northern chairman, Louis W. Menk, recently announced the results of a six-month land use study of their property--2.3 million acres wholly owned and another 6.2 million acres under partial control. Initial plans are being formulated for rural, urban and recreational land developments to meet the demands of the expanding leisure market which they predict will be about 250 billion dollars by 1975 (41).

The rising demand for outdoor recreation and the increasing competition between outdoor recreation and the other uses of land and water resources have focused attention on the value of such resources when used for outdoor recreation. Total recreation in the national park system and the national forests has increased steadily over the years, at an almost constant rate of eight to ten per cent annually.

The fact that the percentage increase remains constant while total usage is increasing means that the actual numbers of visits is rising rapidly as their total number increases. In essence, the more outdoor recreation the population has, the more it wants. In the early 1950's the increase in recreation visits on national forests from one year to the next was three to five million visits; by the early 1960's the same percentage increases produced an actual increase of 10 to 15 million visits (10). An upward trend at a constant percentage rate is in effect, an exponential growth situation which obviously cannot continue on a fixed quantity of resources. The total acreage of National Forest land has remained almost constant for 35 years. There is no clear evidence of a slackening off and the steady and rapid use in numbers of visitors to many outdoor recreation areas is raising serious problems for the maintenance of the quality of the areas concerned. In light of such national trends in the use of outdoor recreation facilities it is easy to understand the sharp increase in concern for visitor use damage to such unique areas as Montana's Spanish Primitive Area (55). As competition for recreation use confronts noncompatible uses, overcrowding and unrewarding outdoor experiences on public land, many people consider their ownership of a piece of private western land as the only way by which they can assure themselves of an outdoor recreation opportunity of acceptable quality. Montana is a prime attraction for recreation land seekers, as is well testified by the magnitude and the

nature of real estate activity and recreation use.

The Discovery of The Big Sky Country

Montana is for sale in the classified sections of national magazines. There are plenty of buyers and the land rush is on to one of the last of the wide open spaces in the Rocky Mountain states. Dr. Layton Thompson's land use research indicates almost "feverish" activity in real estate transactions in Gallatin, Ravalli, Missoula, Lake, Flathead, Lewis and Clark and Yellowstone counties (77). A 1970 survey by the State Department of Planning and Economic Development shows land development corporations, many from out of state are buying huge tracts for subdividing, mostly in Granite, Madison, Mineral, Powell, Lincoln and Lake counties (35). Development had also moved into Carbon, Meagher, Garfield, Glacier, Jefferson, McCone, Phillips, Teton, Valley and Yellowstone counties. A surprising amount of activity was occurring in the central counties of Stillwater, Musselshell and Golden Valley. The 1970 State survey indicated literally dozens of land development schemes reported by county assessors.

The Granite County Assessor reported extensive land development projects including four on Rock Creek, a blue ribbon fishery south of Missoula. Powell County's assessor told the planning department of a seven section subdivision development at Helmville by a Spokane firm. Cascade County's assessor described a California operator who was

selling inaccessible, submarginal land to unsuspecting people from Utah and California who had no easements to get to their worthless purchases. Ten or forty acre tracts of hills, rocks and trees in Musselshell County are being sold all over the country. Regardless of the attitudes of many Montanans that some of these operations amount to a swindle of unsuspecting purchasers, the fact remains that many of these people are getting exactly what they wanted and there are many more anxious buyers. What worries Montanans most about all this development is the impending collapse of the western way of life and severe alteration of historic recreation patterns.

The small farms (1000 acres or less) are being forced out of business by a number of market factors and governmental programs which in effect bestow favours on big corporate farms (3). Small farmers are unable to become big farmers when good farm land sells for subdivisions and other developments at a price much higher than could possibly be justified for farming purposes. Frequently, only the very large corporations, capable of marshalling huge financial resources can compete in the purchase of land for farming purposes. Such developments, frequently by out-of-state corporations, worry local people because they limit access to the public lands around them. A typical Montana example of such a situation is the lock-out of a northern route to the Gallatin National Forest by a large corporate ranch (18) (20). Such occurrences have become so widespread throughout the Intermountain West that of the

110 million acres of wildlife habitat on the public domain scattered from the Rocky Mountains to the Pacific; more than 16 million acres are considered inaccessible, with at least 5.4 million acres blocked off by operation of private lands (20). Increasingly, outdoorsmen are being pitted against powerful land speculators, developers, investment conglomerates and corporations trading as sportsmen's "clubs" who are buying up and leasing key tracts of private land which blocks access to the public property. Subsequently, the locals find their land and waters being closed after many years of unchallenged public use. Destruction of private property by inconsiderate users has increased trespass violations and access denial problems.

It was inevitable that sooner or later people from "outside big industry" and crowded population centres would recognize the advantages of investing in Montana ranching enterprises. Ranching can satisfy many emotional desires and being a large landowner and rancher adds to ones prestige and has become a status symbol amongst many professional people such as attorneys, doctors, company executives and stock brokers. Besides the investment and prestige attributes there are other benefits to be derived from the purchase of large tracts of western property.

Owning a ranch with private hunting, fishing and other recreation amenities is not only of great value to the owner and his family but it constitutes a unique private club for entertaining guests and business associates. Frequently this phase of the ranch operation can be written

off as a legal tax deduction for business operation purposes. Operating at an apparent loss and participating in government agricultural subsidies and agricultural tax benefits offers even greater opportunities for income enlargement. Because of such monetary benefits and associated recreational values, entrepreneurs are willing and able to pay exorbitant prices for ranch property. This increases all land values. Inability to compete with inflated land prices and high cost of ranch operation is effectively eliminating the small ranch enterprise. In the process of selling out however, many of these displaced ranchers are likely to make more money by the sale of their property to developers than they could ever realize from years of ranch operation. Such transactions frequently result in the disruption of historic recreational use by local people who previously were seldom denied trespass rights.

Granite County's assessor says that one of the reasons for some of the developments along Rock Creek is "to get exclusive control of trout streams".(35). Carbon County's Appraiser says, "We have seen a boom in creek frontage, cabin and cabin site sales unbelievable for this area." Madison County is a prime example of what is happening in Montana. Ten or fifteen years ago there were sixty ranch families in the Madison Valley near Ennis. Now 80 per cent of the land is controlled by six owners from Illinois, Indiana, California and Wisconsin (62). A company called Montana's Treasured Land Corporation bought 1,281 unserviced lots for 15 dollars each in historic Virginia City and by January, 1971

had sold 94 of them for 350 dollars each. Several large subdivision developments are occurring in the Madison Valley and one California developer in announcing his plans stated, "I have travelled all over the United States and this is the prettiest country I have ever seen" (60). This California financed development includes 9000 acres which surrounds the Ennis fish hatchery and extends into the Gravelly Mountains will be divided up into 600 ten or more acre parcels to be sold for summer residences and home sites (60). Another similar residential-ranchette development offers its subdivision lot purchasers exclusive access to part of the nationally famous blue ribbon Madison River. In recent months groups from Ennis have complained to Montana's Fish and Game Commission about denial of access to the Madison River, due to new land developments (35). The activity in land use change in Montana's landscape is mirrored in an examination of the past and predicted increase in recreation and tourism.

Montana Governor Forrest H. Anderson told the Family Camping Federation in Chicago on May 10, 1972 that tourism appears headed for number two spot in Montana's economic picture behind the agriculture-livestock industry (2). Tourism and recreation, now the state's third largest industry is predicted to grow from its present 3,777,600 visitors in excess of 65 per cent in the next fifteen years (38). Lieutenant Governor Thomas L. Judge informed Washington and California

travel agents visiting Bozeman that tourism in Montana which was increasing at about six per cent per year resulted in a 165 million dollar input to Montana's economy in 1969 (23).

Yellowstone and Glacier National Parks act as the main attracting agents in initially enticing recreationists to Montana. Although only a relatively small part of Yellowstone National Park actually lies within Montana borders, three of the five entrances to Yellowstone are accessible only by travelling through part of Montana. Annual visitation to Yellowstone surpassed two million visitors since 1965 and is generally increasing, although there was a slight drop in 1971 (45). A record number of visitors journeyed to the park in 1970 with 2,307,280 checking into the entrances (61). Auto travel is now over 600,000 vehicles per season and a survey in July, 1970 showed cars from every state in the union with California, Utah and Illinois respectively being the most prevalent (45) (61). Winter visitation has been increasing at a rate of 20 per cent per year since 1963, a trend which is expected to continue (45). A new visitor total record is expected in 1971 as well as the 50 millionth visitor (61). Glacier National Park passed the one million annual visitor mark in 1969 and received 1,303,000 visitors in 1971 (21).

It is interesting to note however that the Montana Economic Study completed by the Bureau of Business and Economic Research at the University of Montana in 1970 suggested that too much emphasis was being

placed on potential recreation growth as a source of revenue (81). They point out that in the foreseeable future, most Americans will continue to work five days a week and vacations will not lengthen for very many people. Montana has a lot of well-established competition and tourism and recreation commerce encourages the addition of more relatively unskilled, low-paying, seasonal jobs--all of which combine to hold Montana's average per capita earnings well below the national average (82). In general, they conclude that recreation and tourism will not rise appreciably more rapidly than other activities which affect the trade and service industries (81). However, at least one large investment alliance and obviously many others do not agree with these predictions.

Gus Raaum, President of Big Sky of Montana, said the interest generated nationwide by news of Big Sky seemed to refute the university prognostication (59). Raaum said people were almost desperate for a breath of fresh air, and have contacted him by the thousands with a view to using the tourist complex. In addition, he said 1200 to 1500 people want jobs at Big Sky. "These are men who make from \$100,000 a year on down. They want to get away from the cities and develop a business out here. And they will make money." It seems very unlikely that the consortium of big name businesses with the market analysis which they undoubtedly would have utilized would have invested in a recreation/real estate venture as large as Big Sky if there was much

doubt about its financial success. The University of Montana study itself provides information, which, if analyzed in the retrospection of national trends creates some doubt about their recreation growth rate pessimism.

The study points out that the western sector of the United States has 72.3 per cent of the nation's recreation acreage, with only 15.3 per cent of the population (83). The Northeast by contrast has 25 per cent of the national population packed into an area that contains only 4 per cent of the national recreation acreage. Nor is the recreation acreage in the western sector evenly divided--the mountainous region has 48 per cent of the national recreation area for only 4 per cent of the national population, while the Pacific region has 25 per cent of the national acreage for 11 per cent of the population. If, as all analyses indicates, the tremendous national demand for recreation resources materializes, it seems only reasonable that the "return to nature" will occur largely in the western sector and most likely in the mountainous region where the least competition and greatest opportunity for outdoor recreation expansion occurs.

The distribution of recreation acreages and population in Montana also is very enlightening in regard to predicting where the greatest impact from growth might occur in the state. Table 2, pg. 27 indicates the Distribution of Outdoor Recreation Acreage and Population By Fish and Game Planning Regions, Montana (82--pg. 8.18). Figure 2 shows

Table 2. Distribution of Outdoor Recreation and Population By Fish and Game Planning Regions in Montana.

Region	Total Outdoor Recreation Acreage. (1969)	Percentage of State Total	1970 Population	Percentage of State Total
1	5,711,922	29	79,132	11
2	3,783,754	20	100,935	15
3	4,448,749	23	106,694	15
4	3,030,112	15	171,316	25
5	894,573	5	119,227	17
6	605,666	3	73,090	11
7	<u>910,947</u>	<u>5</u>	<u>44,015</u>	<u>6</u>
Total	19,385,723	100	694,409	100

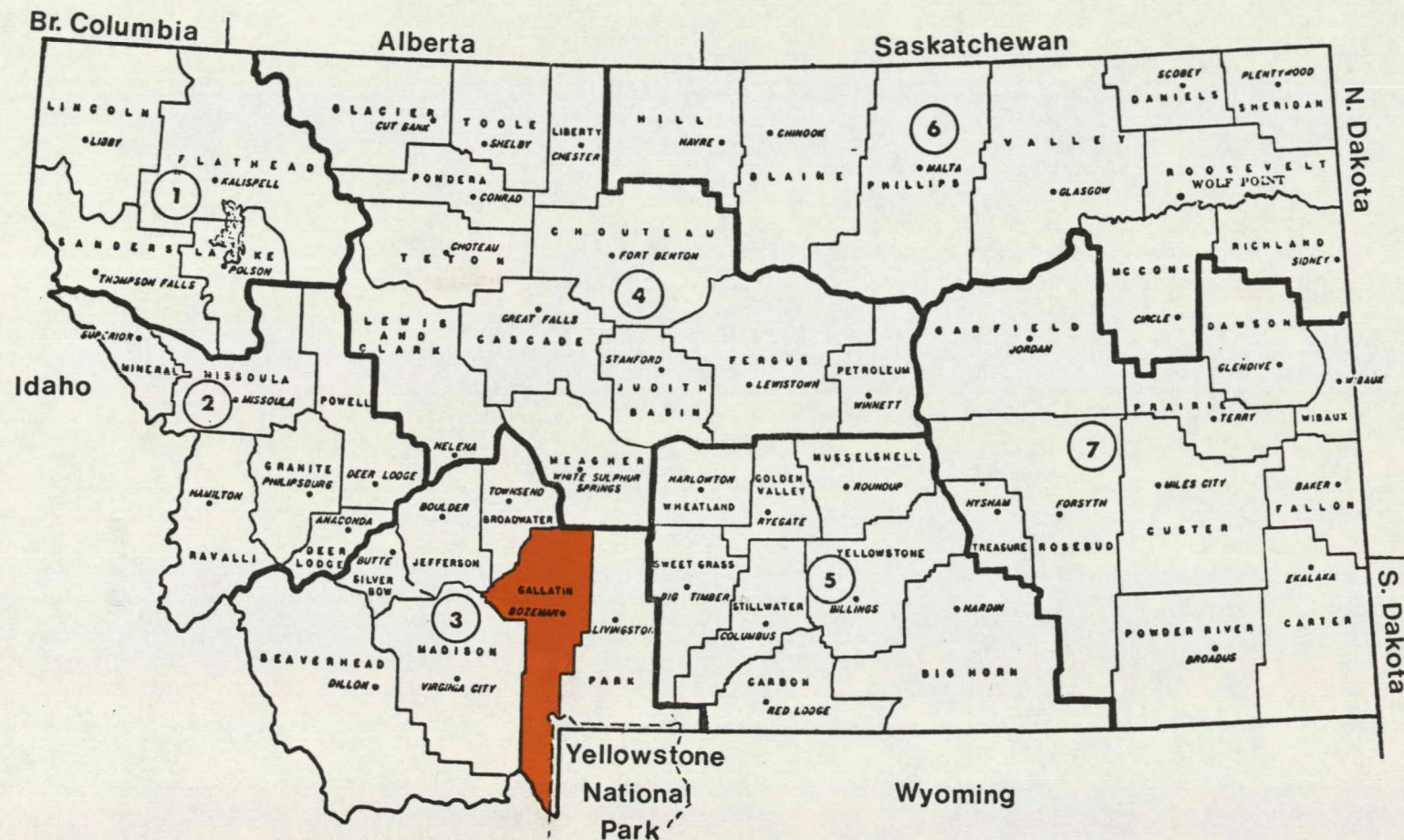


Figure 2. Fish and Game Planning Regions For Montana.

the location of the Fish and Game Planning Regions referred to in Table 2. It can readily be seen that regions 1, 2 and 3, which contain the bulk of Montana's mountainous landscape encompasses 72 per cent of the state's recreation acreage but only 41 per cent of the total population. A reasonable conclusion therefore would be that the greatest impact in recreation or tourism increases will occur in the mountainous western section of Montana. This prediction is further supported by recreationists preference for mountainous landscapes and the impending strip mining of thousands of acres of Eastern Montana with the possible negative effect it is liable to have on recreational attractiveness.

If the reader is willing to assume that the foregoing information does in fact portend the impending demand for use of Montana's land and natural resources, then it should be relatively simple to justifiably conclude that some type of orderly growth should be accommodated in a least wasteful fashion. Many social, economic, political and technological forces have combined to create extravagant uses of natural resources in the past. While this author does not profess to possess more than a layman's amount of insight into the social and political mores of Montana, an observance of the social resistance to planned growth appears to have resulted in a disappointing lack of political decisiveness. It is a mute question as to whether economics shapes or is shaped by such an environment because strong examples of

both can be argued--suffice it to say that economics is an opportunist phenomenon--it shapes where it can and conforms where it must. Use of the land and its resources involves both private and public interests and it appears that fear of encroachment upon private interests may severely compromise both private and public values in the future. If this past failure has resulted from a faulty social organization for equilibrating properly constrained private interests with legitimate public welfare, then at least part of the responsibility for this failure should be attributed to improper decision-making resulting from inadequate knowledge and inappropriate application and presentation of physical techniques used in resource analysis. Herein lies the basic deficiency which lends legitimacy and credence to the subsequently reported research.

Soils and Associated Natural Resources as Decision

Parameters in the Planned Growth Concept

The planned growth concept is one in which need and demand is efficiently accommodated by supply and allocation of natural resources by an enlightened decision-making body. This body most likely would be composed of a number of elected or appointed individuals, and in the United States it theoretically carries out its function in a state of informed participatory democracy. However, it is nearly impossible for these decision makers to be totally informed about the

intricacies and dynamics of the lithosphere and the biosphere and so decisions, out of practical necessity, are commonly made in a partial knowledge vacuum. As unfortunate as this may be it is even more deplorable that existing knowledge is unused because of a lack of appropriate interpretation from a professional jargon into an applicable and readily understood form. Soil, long recognized as one of the nation's basic natural resources is attaining a new perspective as those who invest large amounts of capital in physical facilities in or on the soil are finding newly interpreted soils information to be as valuable to their diverse purposes as it always has been to plant and animal husbandmen.

Initially, soil maps and reports were used mainly for farming, ranching and forestry purposes and the information was assembled with those uses in mind. In a rapidly urbanizing and expanding industrial economy, however, soil maps are being widely used to predict site suitability to support houses and structures, to absorb septic tank effluent, to provide stable road foundations, to carry pipelines, to develop lawns and playgrounds and to permit lasting installations of many other kinds. As savings were demonstrated and potential disasters averted, a growing demand for soil interpretation and use capacity predictions have increased dramatically. The cost-benefit ratio of one of the newest developments in resource planning technology--soil interpretations for nonfarm use is startling. Most soil surveys for

such purposes pay for themselves in one year and many promise a return benefit of 100, 200 or more times the cost in the 25-or-so years of their usefulness.

A. Klingebiel, Director of the Soil Survey Interpretation Division of the Soil Conservation Service, United States Department of Agriculture has reported on many situations where use of nonfarm soil interpretations have or could have saved much expense and grief in land development projects (32). Some of his examples are:

Sewage System, Massachusetts: The town of Cohasset saved more than \$250,000 on its sewage system by using a Soil Conservation Service soil survey which showed that less than one per cent of the town area was suitable for onsite sewage disposal.

School Grounds, Virginia: Fairfax County lost \$250,000 in avoidable cost by selecting a poor school site when the unconsulted soil survey showed favourable land 500 feet away.

Water Main, Michigan: A town near Detroit is out \$200,000 because its new water main was constructed across a 600 foot wide area of deep peat which was shown on the unused soil maps.

Residences, Virginia: More than 100 homes in the suburbs of Richmond were flooded resulting in several

hundred thousand dollars worth of damage. This happened two years in a row. A soil survey would have spotlighted this hazard.

The merit of using soil interpretations for planning guides has been so well demonstrated that many states and counties are requiring mandatory soils investigations before land use change and development proceeds. The Southeast Wisconsin Regional Planning Commission estimates that soil information alone will save Wisconsinites \$300 million in the cost of residential development in a seven county area over the next 20 years (4). It is expected that nonfarm soil interpretations will save \$10 million annually in private building costs in a six county Chicago development area (32). Several states such as Maine and California have been leaders in using soil survey interpretations to guide quality nonfarm development (69) (13) (88). Many individual counties in Illinois, Ohio, Michigan, Virginia, New York and other states have been able to realize substantial savings in averting large public expense by using soil interpretations to steer development away from problem soils. Soil surveys can have great value to highway engineers by providing them with accurate, relatively inexpensive information on the soil over which their road will pass (17). Soil survey information has been shown to be a good basis for interim guidance in flood plain planning if detailed studies are unavailable (52).

These interpretations of soil maps are statements or predictions based on research and experience of the nature and severity of problems or limitations of the kinds of soil suitable for various alternative uses. These interpretations which are made by relying on a large amount of local experience and/or observation, and limited physical and chemical data, are for a wide spectrum of potential uses in the area covered. However, a 1971 Joint Task Force of The Western Association of Agriculture Experiment Station Directors and the United States Department of Agriculture recognized that to a considerable degree, the public, planning, zoning and similar activities were moving ahead without adequate research and education in this area (19). The Task Force, among other things, recommended a strengthening of educational services in the area of alternative land uses and the use of soil resource information at this particular time when so much attention and activity is focused on land use and environmental and ecological planning. Moreover, there is much information and many useful concepts available that are not known or readily available to the people who can or will use them. The Task Force emphasizes the importance of recognizing that because our land is a nonrenewable, limited resource, land use and planning are of paramount concern to our total society and therefore there is a great urgency in soil appraisal research directed towards efficient education of decision makers. One of the specific research recommendations is for quantification of interpretive data

now in use in order to effect a better understanding and practical comprehension by potential users (19).

II. OBJECTIVE OF RESEARCH (to Demonstrate the Use of
Soils and Associated Natural Resources as Decision
Parameters in the Regional Planning Process)

Although the objectives of the research reported in this thesis were established approximately two years prior to the 1971 report of the Task Force, it is significant that the research purposes defined in 1969 are in very close harmony with those identified by the Task Force as having high priority in 1971. Specifically, the objectives of this research project are:

1. to obtain basic natural resource information pertinent to the regional planning process in an area where rapid growth and land use change is occurring. This natural resource information is to be analyzed and interpreted for the purpose of making land use decisions.

2. to present this information in a suitable fashion so that uninformed persons can understand it. This task involves making the presentation adequately interesting and sufficiently informative in order that persons responsible for making land use decisions can and desire to use the information.

3. to investigate some economic aspects of a land use plan which is based on a "design with nature" concept. It seems rational that long-run economic factors would support rational decisions dictated by physical constraints. An affirmative illustration of such an hypothesis would lend strength to the importance of predictive resource interpretations in the regional planning process.

This research was carried out in Gallatin County, Montana, United States of America. The natural resources investigated were soil and associated resources such as slope, depth to water table, flood plains and geomorphological characteristics. Prior to examining the research procedures however, it is important that the reader be familiar with the past and present trends in Gallatin County which qualify it as being an appropriate site for this research undertaking.

III. GROWTH TRENDS AFFECTING LAND USE CHANGE IN GALLATIN COUNTY, MONTANA

Gallatin County is located in southeastern Montana within the Rocky Mountain Physiographic Province. The county totals 2,517 square miles and is 50 miles wide in its extreme east to west dimension and 116 miles long in the extreme north to south distance. Fig. 2 , pg.28 shows the location of Gallatin County in Montana. Of the 1,610,800

total acres of Gallatin County, about 65 per cent is mountainous, largely within the confines of the Gallatin National Forest. Bozeman, the county seat, is located about 90 miles north of Yellowstone National Park at an elevation of 4,771 feet in the east end of an intermontane basin, the Gallatin Valley. Historically, the economic backbone of the county has been the agriculture-livestock industry. Bozeman is the home of Montana State University which has largely contributed to education being the second most important commerce activity in the county.

Gallatin County takes its name from the sparkling river which rises in Yellowstone National Park and which was first sighted by Lewis and Clark in July, 1805 when they arrived at the Three Forks of the Missouri River. The river which drains Gallatin County was named for Albert Gallatin, then Secretary of the Treasury under Thomas Jefferson.

The discovery of gold along Alder Creek Gulch gave rise to a stampede of prospectors who erected Bannock and Virginia Cities in the early 1860's. Unsuccessful miners were attracted to the fertile Gallatin Valley and established the first settlement known as Gallatin City in 1862 near the present town site of Three Forks. In 1864 John M. Bozeman led the first wagon train through the now famous Bozeman Pass and with the help of Daniel E. Rouse and Wm. J. Beall, layed out a townsite. Although John Bozeman was killed by Blackfeet Indians near Livingston in April of 1867, his legend lives on in the many local

places which bear his namesake. Fort Ellis was established to control hostile Indians in 1867 and the Northern Pacific Railroad reached Bozeman in 1883. The towns of Three Forks, Belgrade and Manhattan were established in 1882, 1883 and 1884 respectively. West Yellowstone which is near the southern tip of Gallatin Canyon was settled in 1907 and became the official western entrance to Yellowstone Park in that year.

Topography is largely responsible for the changeable climate in Gallatin County, and the mountainous section characterized by the Gallatin Canyon in the south half is generally wetter and cooler than the broad floor of the Gallatin Valley in the north half. West Yellowstone has a normal annual temperature of 35° F. and 23 inches of annual precipitation while Bozeman has an average annual temperature of 42° F. and 18 inches of annual precipitation.

The Three Forks structural basin which includes the Gallatin Valley, the Madison Valley and the lower Jefferson River Valley was formed as the result of crustal movements in early Tertiary time and is one of the largest intermontane basins in Montana. During and subsequent to the formation of the basin, continued downfaulting and/or downwarping interrupted through drainage. At about the same time the basin became filled to a depth of 4000 feet with volcanic ash and with sand, silt and clay eroded from the surrounding highlands and deposited under both lacustrine and terrestrial conditions. Resumption of through drainage

in late Tertiary time resulted in extensive erosion of these beds. A subsequent mantle of alluvium was deposited in much of the basin in early Quaternary times. The diverse nature of geologic parent materials ranging from fine grained lacustrine deposits to cobbly alluvium has given rise to widely divergent kinds of soils.

Dark coloured soils occupy foothills and mountain slopes in the southeastern part of the valley floor in an area bordering the Gallatin and Bridger Ranges. The topsoil is dominantly silty. Subsoils of the Bridger series which occupy higher mountain slopes and outwash fans contain many rock fragments while those of lower elevation series such as Bozeman are silty materials relatively stone free down to six feet. Further west in the valley extending from Gallatin Gateway through Belgrade and up the east side of Camp and Dry Creeks, two soil textures predominate, the silty soils such as Amsterdam and gravelly soils such as Beaverton. Soils extending from Camp and Dry Creeks to the western side of the valley range from fine sand to silt loam in texture. All the imperfectly drained soils are of alluvial origin and border main streams. Poorly drained soils such as Gallatin silt loam swampy phase occur in flood plains adjacent to both large and small drainageways. The development of irrigated agriculture south and west of Bozeman has resulted in the well-drained soils of this area having unexpectedly high water tables during the irrigation months of June, July, August and September. Underground water supplies are very extensive in the

Gallatin Valley due to the substantial recharge which occurs in late spring and early summer and a subterranean dam near the head of the Missouri River which holds back underground flow (7).

Soils of the Gallatin Canyon area are generally characterized as being high in rock fragments and occurring on steep slopes. Soils on or in close proximity to the West Gallatin River flood plain in the Canyon are alluvial materials. Those soils above the flood plain have generally developed after previous glaciation or colluvial deposit processes and consequently are high in fragment content. Isolated pockets of slowly permeable clayey soils exist as well as the silty soils of the Taylor Fork area. Canyon soils are particularly susceptible to erosion and instability if denuded and this factor combined with steepness of slope and short growing season has restricted any agricultural enterprise to wild range usage--both for domestic stock and big game wildlife. The soils of Gallatin Valley in contrast are very fertile and are largely responsible for the viability of the agriculture industry.

The Gallatin Valley is one of the oldest and most productive agriculture regions in the state. In 1969 \$4,254,100 of crops were produced on 70,300 harvested acres of irrigated land and 97,400 harvested acres of dryland produced crops worth \$4,174,700 (42). Cash receipts for livestock accounted for \$12,916,900 of a total agriculture value of \$21,345,700. Winter wheat has always been the largest dry land crop with 52,000 harvested acres averaging 43.0 bushels per acre, the second

largest average yield per acre in the state in 1969. Most of the irrigated land is used for forage which averaged 2.59 tons per acre in 1969, again the second highest average yield per acre in the state. It is generally considered that a relatively favourable combination of fertile soils and less rigorous climate have permitted Gallatin County to consistently out-produce almost all other Montana counties on an average per acre basis. This reliable and steady agricultural bounty has been instrumental in facilitating the strong growth of Bozeman. The population of Gallatin County by increasing at a 24.8 per cent rate from 26,045 in 1960 to 32,505 in 1970 was one of the largest percentage increases of Montana's 56 counties (80). This in itself has had substantial affects on county activities but it is in and around the city of Bozeman where the most obvious changes are occurring.

The 39.7 per cent population growth which boosted Bozeman's 1960 population of 13,361 to 18,670 in 1970 ranked Bozeman as one of the nation's fastest growing cities (80) (89). The economy of Bozeman has demonstrated considerable strength in the past and there are a number of very significant factors which have been and will be important in the continuing development of Bozeman as a state growth centre.

Montana, like the rest of the United States, is experiencing a steady movement from rural to urban centres. This has contributed to Bozeman's rapid growth as an important service centre, and there is little doubt that Bozeman is developing as a major retail-wholesale

trade centre. Consequently much of the present and future commerce activity in the Bozeman area is associated with the expanding trade and service industry. The Upper Midwest Economic Study predicts that the increased activity within the Bozeman district will centre primarily in the areas of manufacturing, construction, retail trade and services, and government with some actual decline in terms of agricultural employment (25). Predictions in the Montana Economic Study support this hypothesis by anticipating a continued decline in agricultural employment but a substantial increase in federal government jobs and a smaller increase in trade and service industries in Region IV which includes Gallatin County (83). In studying the economic feasibility of a proposed convention centre complex for Bozeman, T.A.P. Incorporated concluded that part of the large increase expected in the service and government areas resulted from the strong growth surrounding Montana State University and the development of both winter and summer recreational activities within the area (24).

The importance of the university with its expanding education and research responsibilities within the past ten years is well demonstrated by the surge of activity which grips Bozeman at registration time each September and the relative calm which descends upon the city over summer break. However, the university growth may be slower than anticipated and future development may be curtailed by funding cuts which occurred during Montana's 1971 legislative session and drop-off in

student enrollments. Consequently, there is considerable reason to anticipate that of the three big factors in Bozeman's growth, agriculture, education and recreation and tourism, that recreation and tourism is likely to be the largest contributor to future growth and prosperity in Bozeman.

As was previously indicated the recreation industry in Montana is expected to be a very significant economic activity, and a major part of the growth is taking place within the Bozeman area, both in terms of winter and summer sports. The summer activity centres around the bountiful outdoor recreation opportunities of the natural resources of the area, including tremendous mountain scenery, rivers, streams, forestry and wildlife which annually entice tourists, recreationists and new home seekers by the thousands. Bozeman's geographic location in proximity to Yellowstone National Park, the Gallatin National Forest, the Spanish Peaks Primitive Area and the blue ribbon fishery in the Madison, Gallatin and Yellowstone Rivers is of great importance in attracting people to Gallatin County. The Gallatin Canyon area is renowned for its beauty and recreational attributes. Over one-half million people annually enter the west entrance of Yellowstone Park through the West Yellowstone gateway (74). One can logically assume that approximately the same number leave by this gate which indicates that the tourist activity within the Gallatin Canyon is very significant. With the development of Big Sky of Montana, a recreational/real

estate complex offering nature lovers the grandeur of unspoiled natural wonders without the sacrifice of all the modern comforts and conveniences (6) in the West Fork-Lone Mountain area of the upper Gallatin River, it is certain that many more people will visit and eventually reside in Gallatin County. Even without Big Sky the trends in use of Gallatin County recreational resources indicates substantial increase. Table 3, pg.44 shows the changes in visitor day use in the Gallatin National Forest since 1967. A visitor day is defined as one person

Table 3. Visitor Days and Per Cent Increase in Visitor Days on the Gallatin National Forest

	Visitor Days	Per Cent Increase Over Previous Year
1971	1,676,500	9
1970	1,526,500	6.5
1969	1,428,300	6.8
1968	1,331,100	6.4
1967	1,251,300	---

spending a full twelve hours in the Gallatin National Forest (24). The Gallatin Forest has historically experienced more recreation visits than the other Region One forests. One of the largest increases in recreational activity in the Gallatin National Forest has occurred in

winter use. Table 4, pg. 45 details the increase in skier visits to Bridger Bowl, located 18 miles northeast of Bozeman on the east-facing slope of the Bridger Range. The tremendous rate of increase of skier days at Bridger Bowl was interrupted by a poor '71-'72 season caused by a late opening, an early closing and unusually high winds. Skiing

Table 4.. Skier Visits and Per Cent Increase in Skier Visits at Bridger Bowl.

Season	Skier Visits	Per Cent Increase Over Previous Years
71-72	140,128	-0.62
70-71	141,000	+24
69-70	114,000	+58
68-69	72,265	+38
67-68	52,425	---

has been growing nationally at approximately 25 per cent per year.

Bridger Bowl, with the exception of the '71-'72 season has consistently been above that annual growth, running in the 30 to 35 per cent increase range. This high rate of increase can be expected to continue in view of the Big Sky ski development, improved air transportation, enlarged Bozeman accommodations and increased national advertising. Favourable snow conditions and terrain combine to make the Gallatin Forest a

destination of national renown for snowmobile users as well as skiers (86).

Two of the largest rallies on the international snowmobile tours are held at West Yellowstone. An early season December rally usually draws more than 4,000 people and a late season March rally attracts about 6,000 people. The 120 mile "Big Sky Snowmobile Trail" between West Yellowstone and Bozeman attracts both in-state and out-of-state visitors. Growing recreation use in the Gallatin National Forest has resulted in increasing conflict with historic uses such as grazing, mining and lumbering. The Forest Service is presently engaged in a concerted effort to fulfill local, state, regional and national goals, both economic and social, by multiple-use planning which includes public participation in determining priorities or "key-values" in resource management (86) (87). As strongly as the recreation impact of temporary and permanent migration to Gallatin County is, the effect is less dramatic than the changes which occur in real estate transactions, county government activity, transportation and nonfarm land development.

In the fall of 1970 the Gallatin County Clerk and Recorder's Office reported that they had filed as many plat changes in the three past years as were handled in all the previous years since 1864 (73). The single item that increased the work load in the office was the recording of subdivisions and the platting of land. This comes about

with more and larger areas of land being divided into acreages. In 1970 the county assessment office reported a 23 per cent increase in listings over 1966 and an increase of 80 per cent in office paper work.

There is a trend toward larger blocks of land being officially committed to subdivision development outside of the city limits. In 1971, 1077 acres were registered for subdivision development with the city-county planning office, much more than the 539 acres in 1970. A similar trend for subdivision plats is being established in 1972 with about 450 acres presented for subdivision approval at one meeting (56) (40). The assessed value of subdivision tracts increased from \$933,685 in 1967 to \$1,284,910 in 1971 (58). Assessed improvements on subdivision land increased from \$5,448,045 in 1967 to \$6,974,481 in 1971. Mobile homes assessed for the years 1967, '68, '69, '70 and 1971 have increased from 640 to 739, 956, 1028 and 1584 respectively.

Development outside of Bozeman's city limits has resulted in an annual rise in the number of septic tank permits issued, and records show a 1970-'71 increase of 31 per cent in septic tank installations (75). Treasurer's office records show 22,998 vehicle registrations for 1971, a 36 per cent increase over the 16,917 registrations in 1967. More cars, more people and more outlying developments have created increased work problems for county road maintenance. Gail Thompson, Head of the Gallatin County Roads Department stated that a large part of their work load increase resulted from scattered residential

development which was quickly followed by requests for road and access improvements to areas which had adequately served in a relatively unchanged condition for many years (76).

Montana Power customer accounts out of the Bozeman office increased from 6505 in 1967 to 7264 in 1971 (43). Telephone hookups of 14,393 in February, 1971 show a definite increase over 13,493 in February of 1970 (89). In conducting a study for the Montana Aeronautics Commission, T.A.P. Incorporated pointed out the eight fold growth in passengers at Gallatin Field over the 1960's and predicted another eight fold increase during the 1970's. One of the most interesting results of growth in Gallatin County has expressed itself in real estate activity.

Dr. Layton Thompson has analyzed 665 land sale transactions, part of an investigation of 1200 sales which occurred in Gallatin County between 1965 and 1970 (78). Of these 665 sales, 96 were of 40 or more acres which were defined as farms, 210 were located in officially plat-
ted subdivisions and 359 occurred in an unorganized pattern throughout the county. All of the nonfarm sales were less than 40 acres and most were less than 20 acres in size. Gallatin Canyon river-front property in 1972 is selling for about \$5000 per acre and Gallatin Valley non-farm property is averaging about \$2000 per acre. Farmland in contrast brings \$300-\$500 per irrigated acre and \$175-\$225 per acre for dryland farming operations.

Interviews with several local real estate agencies indicate most inquiries for purchase of land come from out of state, particularly California (9) (22) (14). Most prospective purchasers are interested in investment, recreation and speculative ventures. Prominent Bozeman realtor P. K. Dudley stated that, "good farmland sells for less than a pile of rocks if they're pretty" because the greatest interest is in "recreation property." The present and anticipated market in land development is so great in Gallatin County that four new real estate agencies are being established to share in the activity which is already supporting 15 real estate offices.

The foregoing, although it is only a cursory description of the resources and the nature of trends and activities which characterize the growth in Gallatin County, it is sufficient to demonstrate the propriety of the area as a site for research which attempts to provide information useful for decision making in the regional planning process.

IV. METHODS AND RESULTS

Soil Interpretations For Land Use Planning and Development in the Gallatin Valley Area, Montana

A soil survey of the Gallatin Valley Area was conducted and published by DeYoung and Smith in 1931 (12). The area they surveyed covers 802 square miles, or approximately 30 per cent of the total land area of the county, and includes most of the irrigated land, together with much of the nonirrigated farming and grazing land of the higher valley slopes or benches and the adjacent foothills that border the mountains. All assessment of soil capability was for farm or agriculture purposes and no mention was made of soil suitabilities for nonfarm use. Although almost all the basic information necessary to accomplish nonfarm soil interpretations is contained in the report, this was not done, supposedly because there was no demand. In the fall of 1969 a project was undertaken to provide such interpretations under the guidance of G. A. Nielsen, F. A. Boettcher and R. L. Moshier¹.

Information used in making the soil interpretations came primarily from the 1931 survey, but it was augmented with knowledge gained from local experience and observation. A description of the Gallatin

¹ See Appendix, page 125.

Valley soils is contained in the Appendix, page 139 to page 154. An unpublished Soil Conservation Service memorandum for Interpreting Engineering Uses of Soils, which has since been revised, was used to evaluate soil and soil associated conditions which would constitute various degrees of hazard for specific uses. Each of the 32 soils occurring in the Gallatin Valley was given a suitability rating for each of 16 different uses. Some of these uses are building foundations, septic tank filter fields, roads and streets, recreation areas and sanitary land fills. A complete list of all uses considered appears on page 129 in the Appendix. Fifteen separate soil and landscape properties or hazards such as flooding, slope, frost heave potential and load bearing capacity were considered when rating each soil as having a slight, moderate or severe limitation for each particular use. A complete list of all fifteen soil or soil associated properties and hazards considered appears in the Appendix on page 134. Soils rated as slight are relatively free of limitations or have limitations that are easily overcome. Soils rated as moderate have limitations that need to be recognized but can be overcome with good management and careful design. A severe rating indicates limitations that are difficult or costly to overcome. A severe rating does not mean the soil cannot be used for a specific use, but it means that careful planning and design and very good management are important. These interpretations are designed for general planning. On-site investigation is needed for

specific design and construction because all soil differences which occur in the field cannot be shown on a general soil map. The 16 selected uses of soil and the properties considered important in evaluating soils for each use are given in the Appendix, page 129. The estimated Gallatin Valley soil limitations or suitability for selected uses are displayed in Appendix Table, pages 136, 137 and 138.

Colour-Coded Soil Limitation Maps--Gallatin Valley

Transparent maps on which soil limitations--slight, moderate and severe were colour-coded as green, yellow and red respectively, were prepared at the same scale as the original soil map for each use considered. The map material used was .003 inch transparent, matte finish mylar and the green, yellow and red colour material was transparent, matte finish, adhesive-backed film. The soil map placed underneath the transparent mylar provided the base lines for applying and cutting out the appropriate coloured adhesive film with sewing needles. In this way individual soil suitability maps showing colour-coded slight, moderate and severe soil limitations were created for septic tanks, foundations for low buildings with basements, roads and streets and cropping. A base map showing the survey outline boundaries, cities, rivers and major transportation routes was prepared to overlay the limitation maps in order to facilitate geographic orientation. These maps at a scale of 1 inch = 1 mile have overall dimensions of 51

inches long and 40 inches wide. These maps are on file at the Department of Plant and Soil Science, Montana State University, Bozeman, Montana.

An example of soil limitation maps for cropping and roads and streets appear on pages 54 and 55 respectively. The single use maps showing soil limitations for septic tank drain fields, roads and streets and foundations can be overlain to produce a composite map showing a variety of colour combinations from solid red to solid green. Figure 5, page 56 shows the effect of laying the septic tank drain field soil limitation map over the building foundations soil limitation map. Figure 6, page 57 shows the result of laying the roads and streets soil limitation map over both the septic tank drain field and building foundations soil limitation maps. The range of colours produced is an overall indication of the geographic variability of soil limitations for nonserviced developments and represents various degrees of subdivision development difficulty.

Prior to the construction of the large maps using coloured adhesive film as described above, similar maps of the Bozeman area were made on mylar using felt-tip marking pens. These maps were sprayed with a protective plastic material. When affixed to a firm backing, these maps are easily transported and are used for presentations when the large size of the valley maps precludes their use. The smaller maps measure 40 inches long and 21 inches wide.

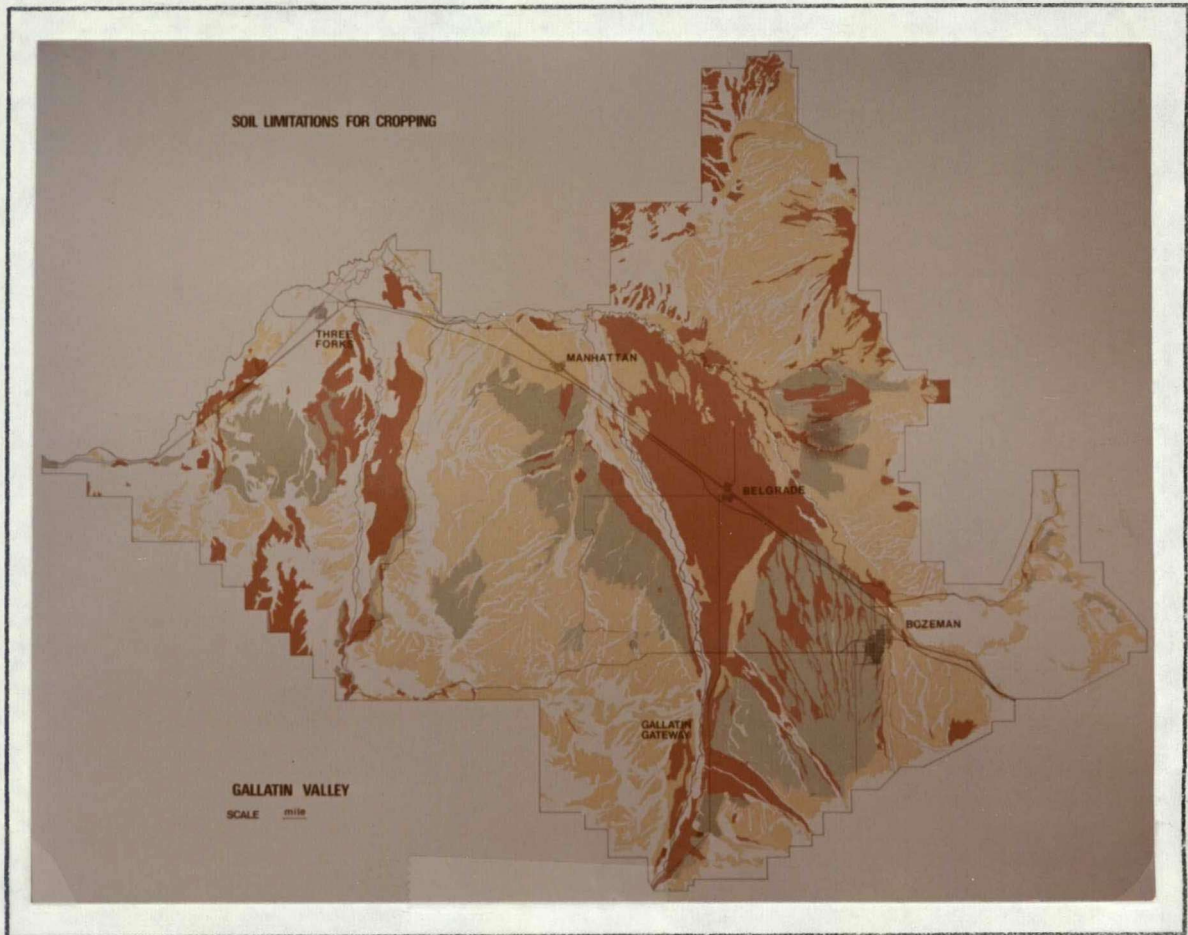


Figure 3. Soil Limitations For Cropping.

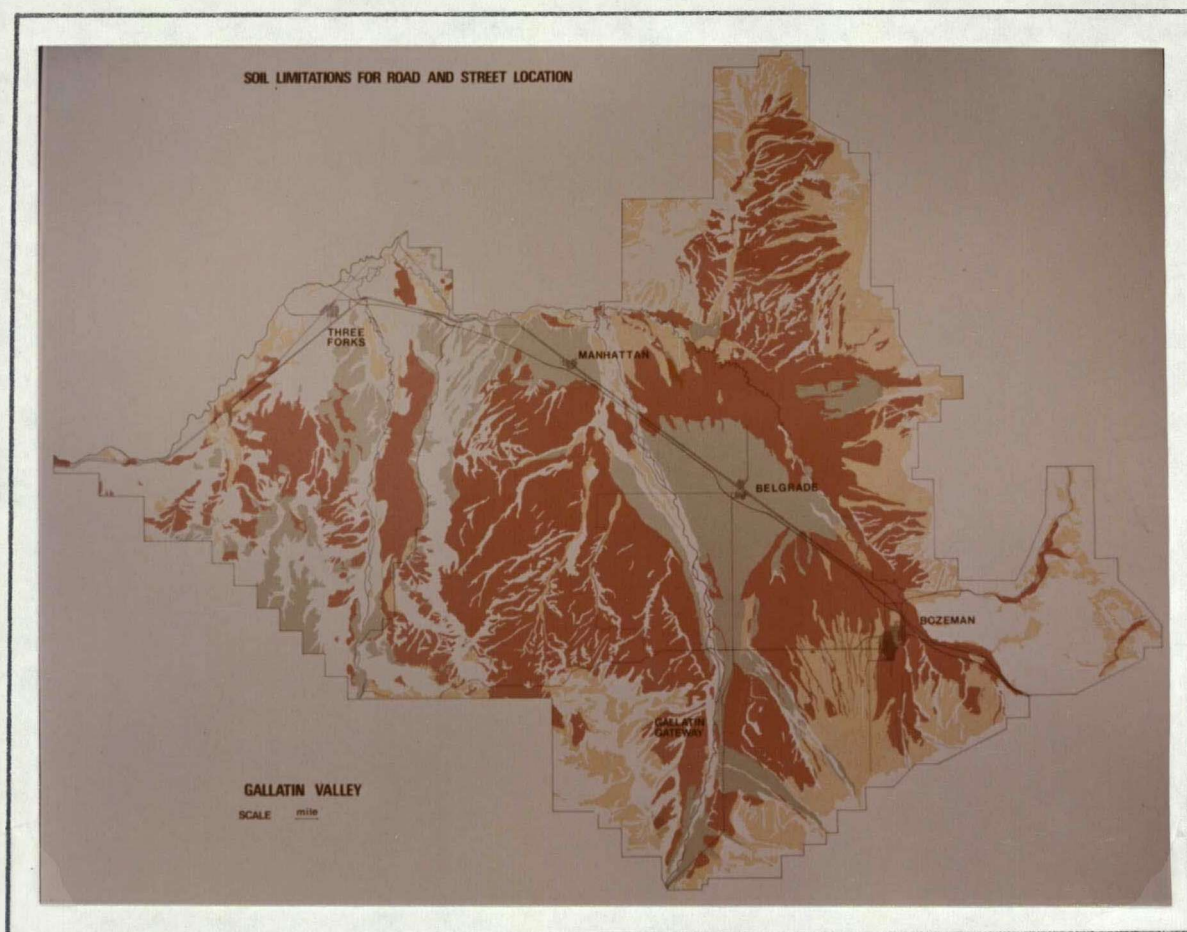


Figure 4. Soil Limitations For Roads and Streets.

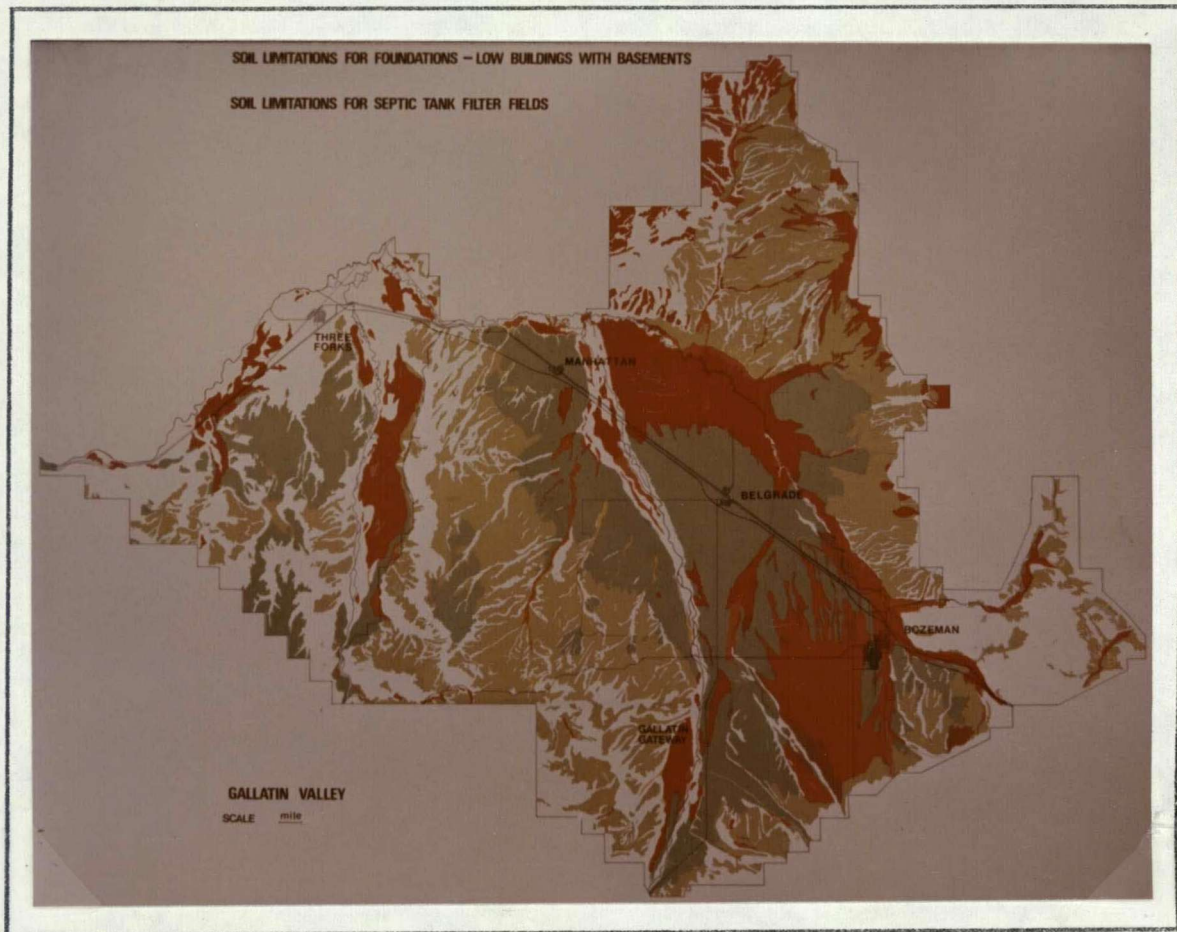


Figure 5. Soil Limitations For Septic Tank Drain Fields and Foundations For Low Buildings.

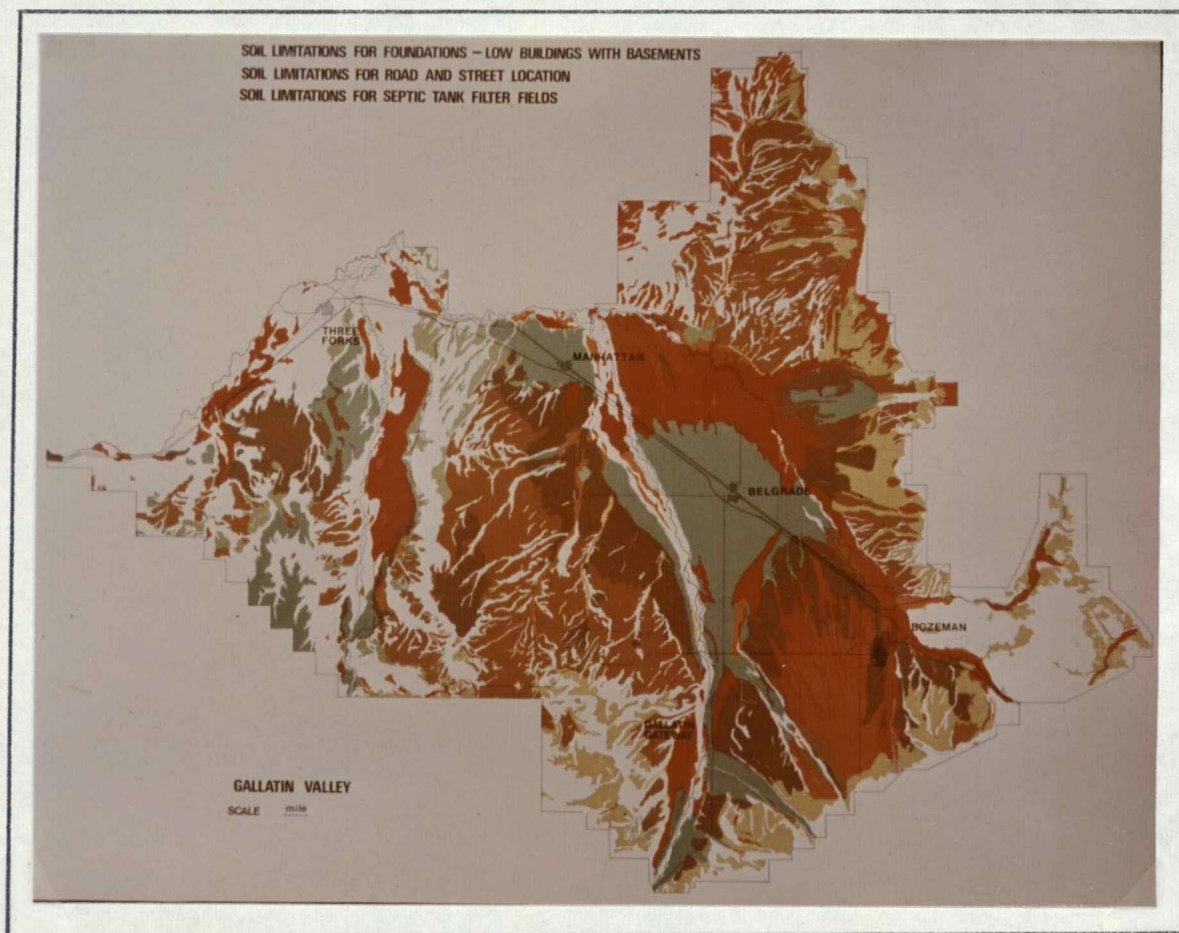


Figure 6. Soil Limitations For Roads and Streets, Septic Tank Drain Fields and Foundations For Low Buildings.

All of these maps are used in public presentations to audiences concerned with land use planning. Although most presentations have been in Gallatin County, the maps and information have been presented to audiences as far away as Edmonton, Alberta and St. Louis, Missouri. A documentation of the presentations appears in Appendix table 12, page 155.

Shortly after the announcement of the proposed Big Sky Montana development in the Gallatin Canyon (5), Montana State University received a National Science Foundation Grant to study the Environmental Impact of a Large Recreational Development on a Semi-Primitive Environment. Consequently the soil and associated natural resource interpretations project was expanded from the valley up the Gallatin Canyon to the northern boundary of Yellowstone National Park.

Soil Survey of the Gallatin Canyon Area, Montana

A soil survey under the direction of A. Olsen, Soil Scientist with the Helena office of the Soil Conservation Service was carried out for the Gallatin Canyon area in the summer of 1970. The area surveyed encompassed 117,500 acres, beginning at the mouth of the Gallatin Canyon approximately 15 miles southwest of Bozeman, and extends to the Yellowstone Park boundary, about 30 miles north of West Yellowstone. The survey area includes the flood plain of the Gallatin River and its main tributaries as well as the adjacent hills and steep bedrock

mountains on either side of the valley. The survey boundary shown on the General Soils Map in the Appendix pocket extends approximately four miles into Madison County to a point on the west side of Lone Mountain, and four and one-half miles to the east of the Gallatin River in the vicinity of Elkhorn Creek.

The field survey was carried out at a reconnaissance level of detail and delineations were made on the basis of 18 different soil or soil complex mapping units. The mapping units were established after a two week initiation period during which time soils and landscapes were examined throughout the proposed survey area prior to actual mapping. Field mapping was done on aerial photos at a scale of 4 inches = 1 mile or 1:15,840. Odd numbered aerial photos within flight lines were used as field sheets and even numbered aerial photos were used to provide stereo coverage for air photo interpretation purposes. Standard soil survey procedures of air photo interpretation, landscape, vegetation, elevation and aspect considerations were used to augment actual soil investigations in determining placement of soil delineations. The original air photos on which field lines were drawn are at the Bozeman office of the Soil Conservation Service. Copies of these photos are also on file at the Department of Plant and Soil Science, Montana State University, Bozeman, Montana.

Thirteen individual soil series were identified and correlated with the National Cooperative Soil Survey Program. Each of these soil

series has been described in detail and sampled according to horizonation. This was done to depths of approximately 60 inches at benchmark sites representing a modal member of each particular soil series or variant. Characteristics such as colour, structure, consistence, fragment content and estimated permeability were recorded. These descriptions, site locations and soil samples are on file at the Department of Plant and Soil Science, Montana State University, Bozeman, Montana. A generalized description of all established soil series and other soil mapping units is contained in the General Soils Map located in the Appendix pocket.

The General Soils Map of the Gallatin Canyon shows 10 main groups of soils called soil associations. Each association consists of several different kinds of soils termed soil series. Soil series are distinguished on the basis of natural drainage, texture, depth and certain chemical and physical properties, some of which were referred to above. Thus the General Soil Map does not show the specific kind of soil at any particular place, but associations of several different soils that occur together in characteristic patterns. Soil associations are named for the major soil series in them. Soil series of one association may be present in other associations. The acres of each soil association and per cent composition by series is shown in the Legend and in Table 1 of the General Soils Map report. Each soil association is described in terms of i slope range, ii topography, iii

precipitation range, iv elevation variation, and v major vegetative species present, in addition to specific soil patterns.

Information on Gallatin Canyon climate, recreation, timber and geology appears in the General Soils Map report.

Soil Interpretations for Land Use Planning and
Development in the Gallatin Canyon Area, Montana

All soils were evaluated for each of 16 different uses. Some of these uses are building foundations, septic tank filter fields, recreation sites and suitability as a source of construction materials. A complete list of the uses and significance or importance of soil properties and other factors affecting the use appears in the General Soils Map report under the heading Definition of Selected Uses. Twenty-two separate soil properties or hazards such as flooding, texture, slope and compaction characteristics were considered when rating each soil as having a slight, moderate or severe limitation for each particular use. Ratings used for "suitability as a source of construction materials" were good, poor or fair. A complete list of factors considered appears in the General Soils Map report under the heading, Limiting Soil Properties and Hazards Indicated by Number in Table 1. These soil interpretations for selected uses of land which appear in Table 1 of the General Soils Map report may be used to guide the development of general plans but they do not eliminate the need for on-site soil

investigations for design and construction. A revised draft of the Guide For Interpreting Engineering Uses of Soils was used in making the interpretations of Gallatin Canyon soils for nonfarm purposes (33).

Coded Soil Limitations Maps--Gallatin Canyon

Colour-coded soil limitations maps using green, yellow and red colours to indicate slight, moderate and severe hazards for particular uses were prepared for the Gallatin Canyon area. Maps for all the following uses were constructed: foundations for low buildings, septic tank filter fields, roads and parking, lawns and landscaping, camping areas, picnic areas, playgrounds, and trails and paths. These maps at a scale of 1 inch = 1 mile or 1:63,360, can be used as overlays in a variety of combinations and are similar in appearance and use as the maps previously described for the Gallatin Valley. These Gallatin Canyon Soil Limitation Maps are on file at the Department of Plant and Soil Science, Montana State University, Bozeman, Montana.

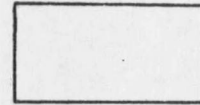
In addition to the colour-coded maps, smaller scale, 1 inch = 4.36 miles, soil limitation maps were prepared. These maps are constructed using a reduced copy of the General Soils Map overlain by boundary outline maps on a light table. The underlying soil boundaries were thus adequately discernible to serve as guidelines in cutting out the film material. Grey tone, dot screen film was used in this case, instead of coloured film, but the process of application and cutting

out with sewing needles was identical. The major difference between the colour-coded maps and the grey tone maps is that the slope factor was removed from the soil rating considerations in the latter. Slope is the most prominent naturally occurring factor which limits soil use and conventional land development in the Gallatin Canyon and in the colour-coded maps was primarily responsible for a near totally red map. Consequently, slope considerations were omitted in preparing the grey tone maps in order to allow expression of other naturally occurring limitations to use. Grey tone maps for foundations for low buildings with basements, foundations for low buildings without basements, septic tank filter fields, roads and parking, lawns and landscaping, camp areas, picnic areas, playgrounds, and trails and paths appear on pages 65, 66, 67, 68, 69, 70, 71, 72, and 73 respectively. The grey tone slight, moderate and severe soil limitations legend appears on page 64. A composite recreation map in which soil limitations for camping areas, picnic areas, playgrounds, and trails and paths were analyzed, again omitting slope, and presented as slight, moderate and severe ratings for overall recreation suitability for the activities included appears on page 74.

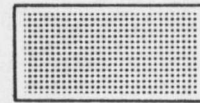
Computerized Slope Map

Because slope is such an important factor affecting resource development in the Gallatin Canyon area, a separate slope classification

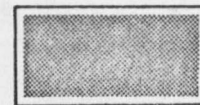
SLIGHT



MODERATE



SEVERE



SCALE

1 inch = 4.36 miles

**Figure 7. SLIGHT, MODERATE AND SEVERE SOIL
LIMITATIONS FOR FIGURES 8 THRU 17**

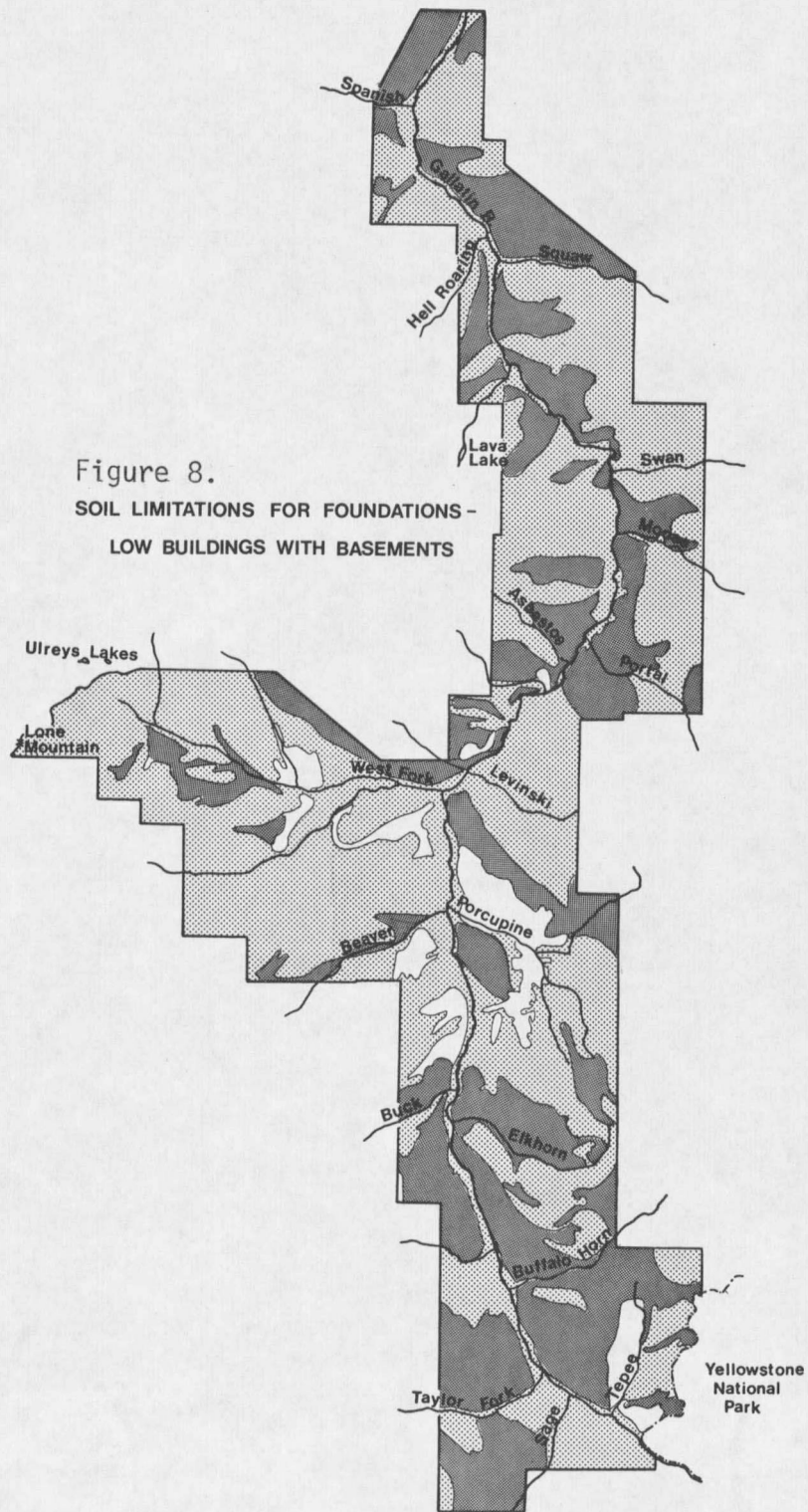
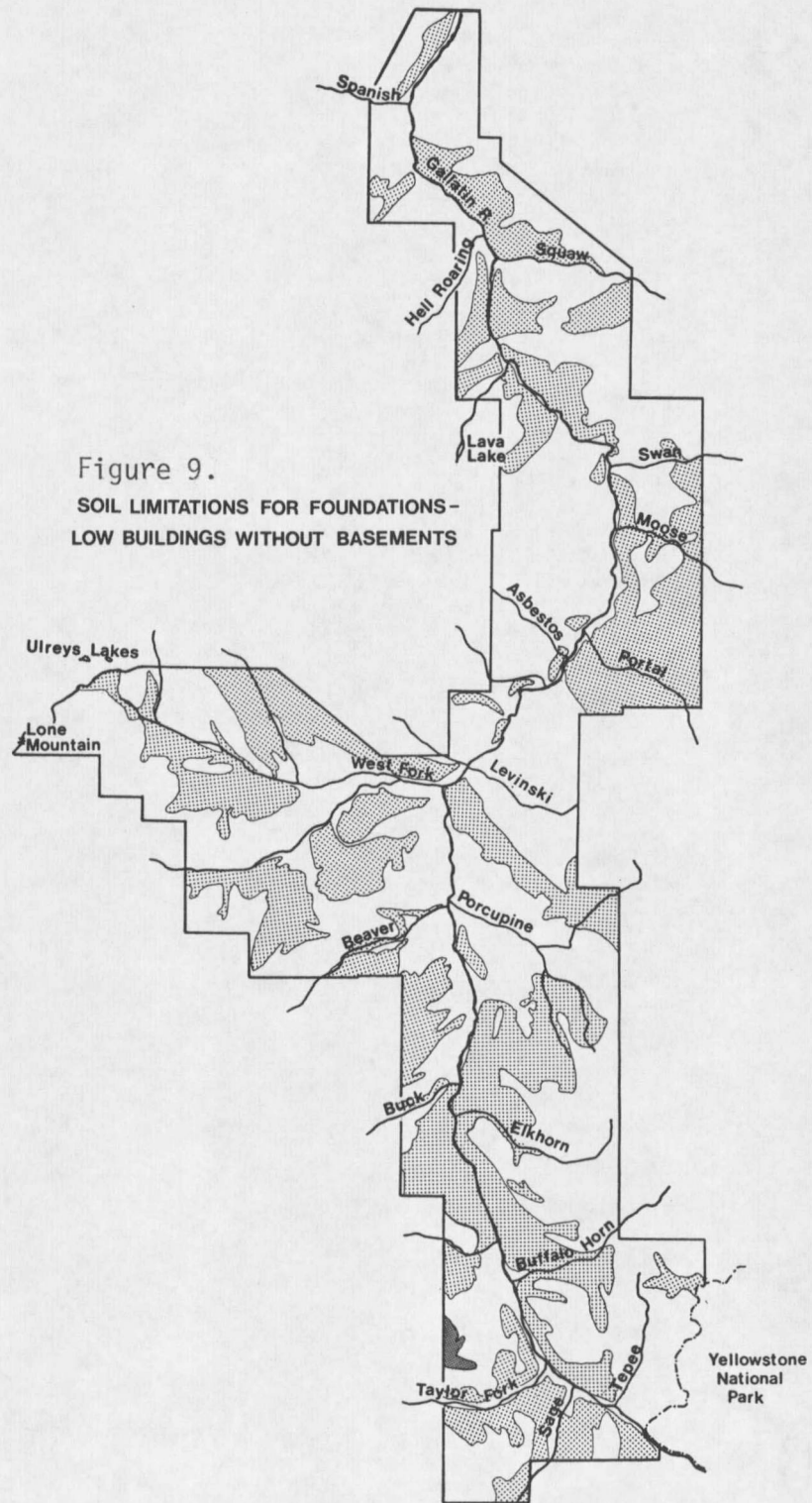


Figure 9.
SOIL LIMITATIONS FOR FOUNDATIONS -
LOW BUILDINGS WITHOUT BASEMENTS



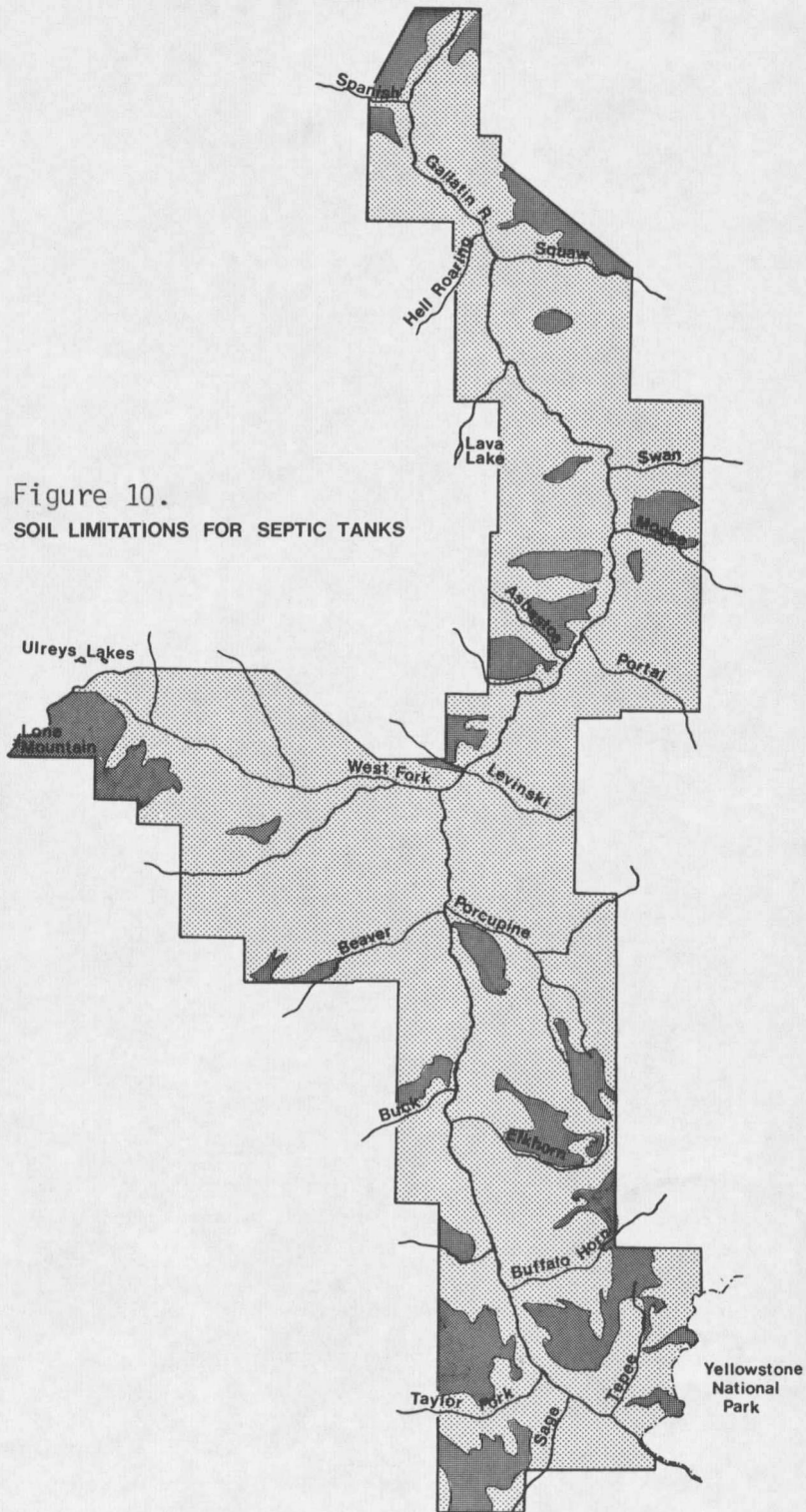


Figure 11.
SOIL LIMITATIONS FOR ROADS AND PARKING

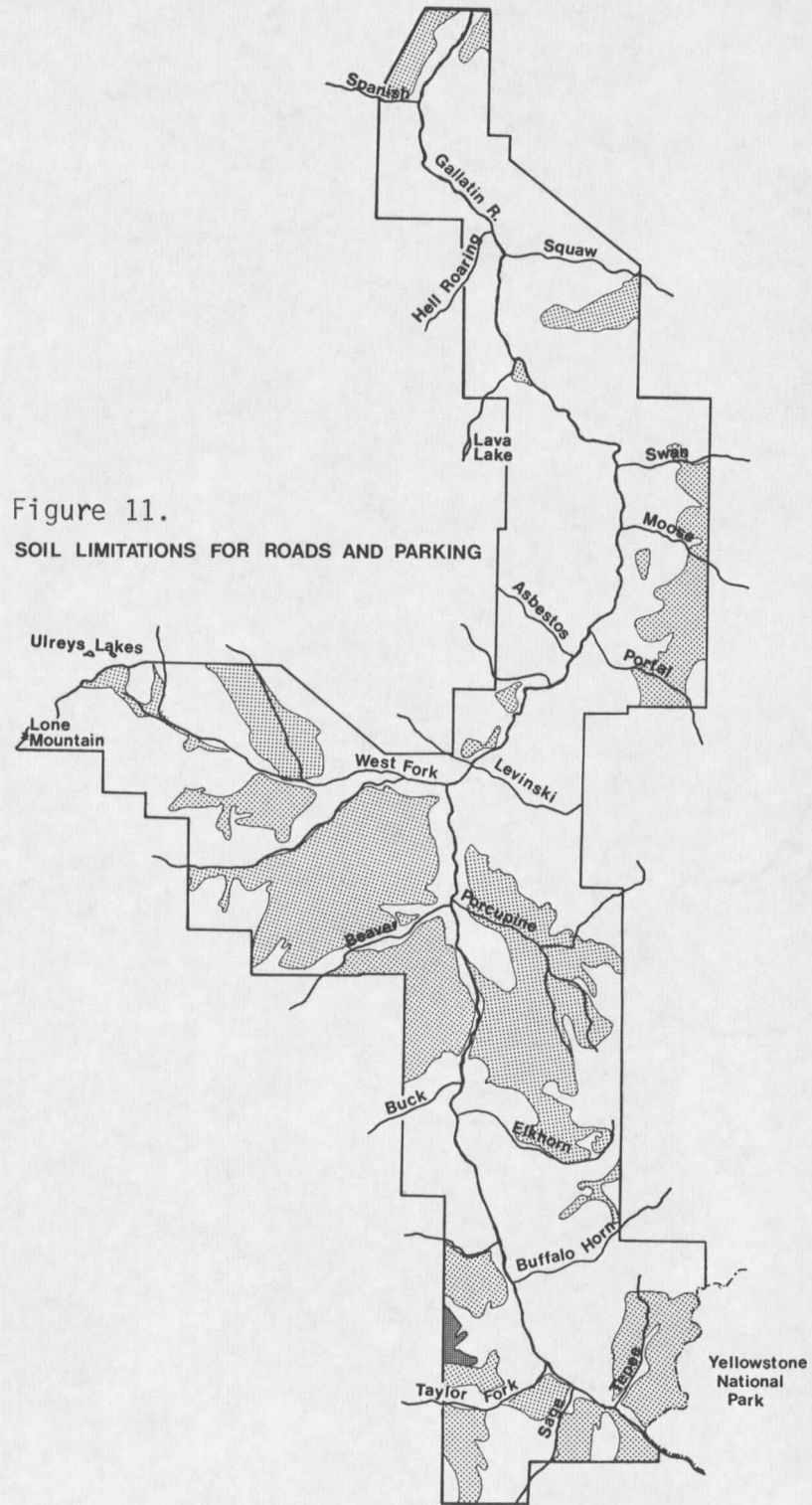


Figure 12.
SOIL LIMITATIONS FOR
LAWNS AND LANDSCAPING

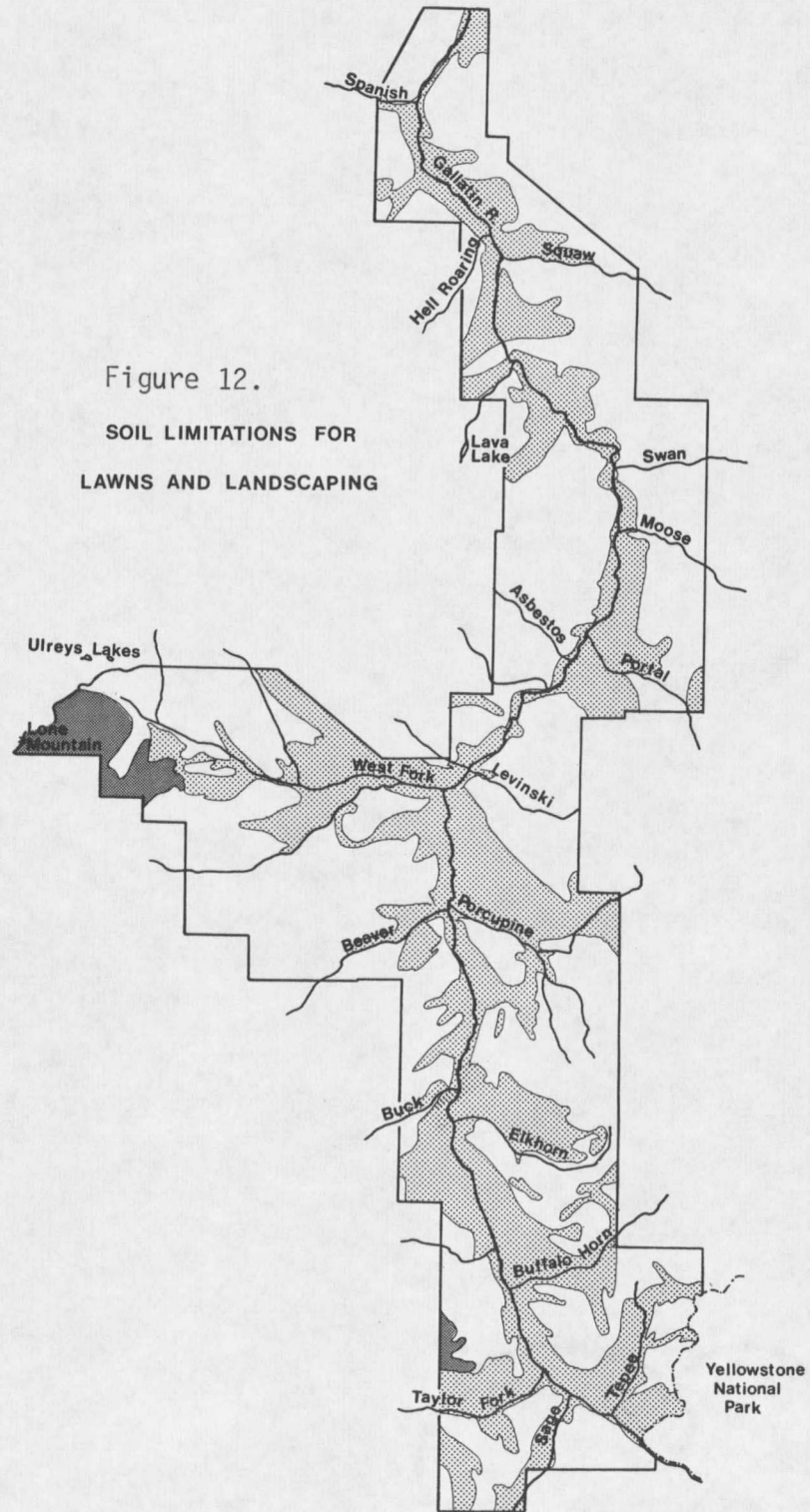


Figure 13.
SOIL LIMITATIONS FOR CAMPING

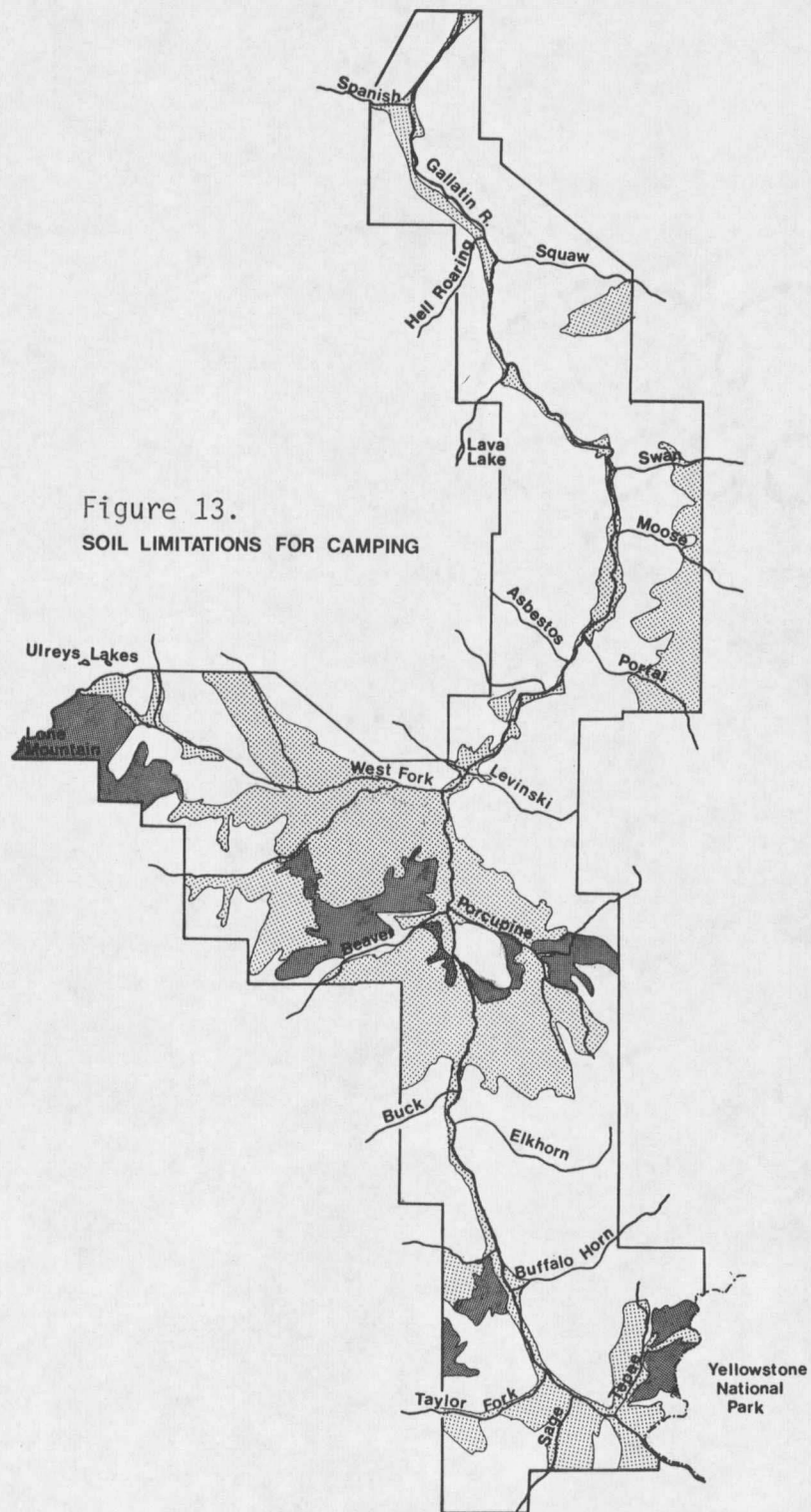
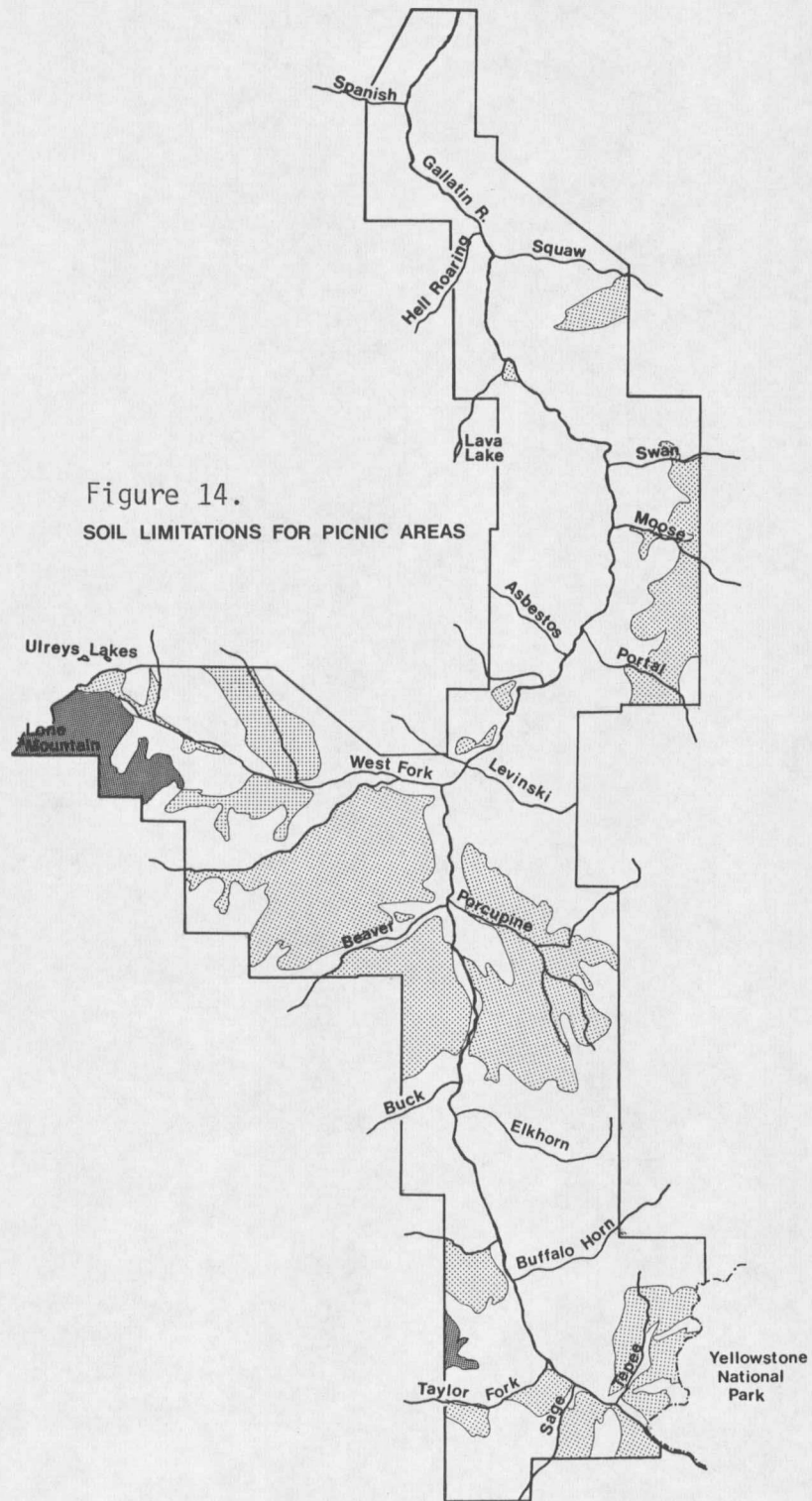


Figure 14.
SOIL LIMITATIONS FOR PICNIC AREAS



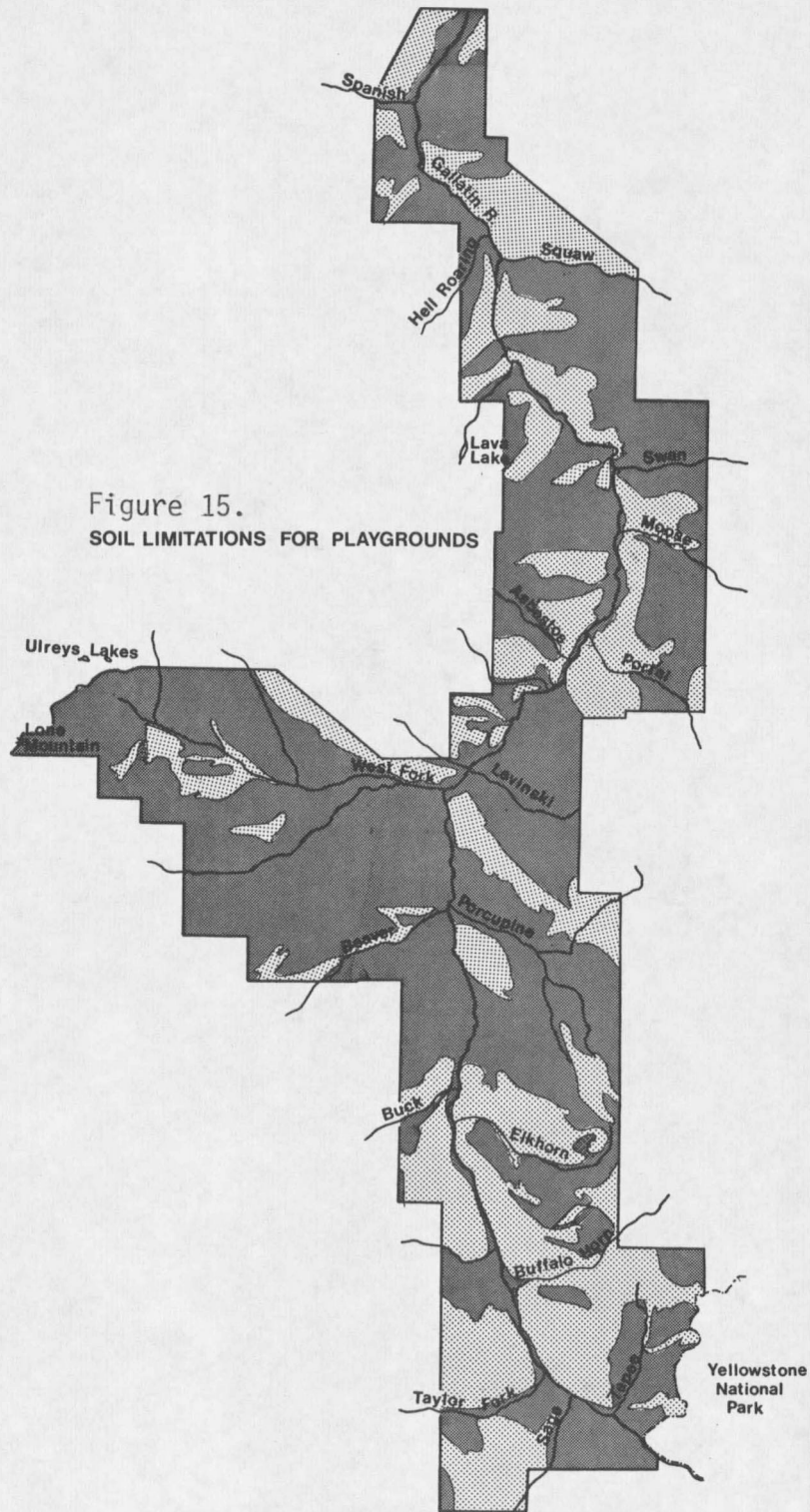


Figure 16.
SOIL LIMITATIONS FOR TRAILS AND PATHS

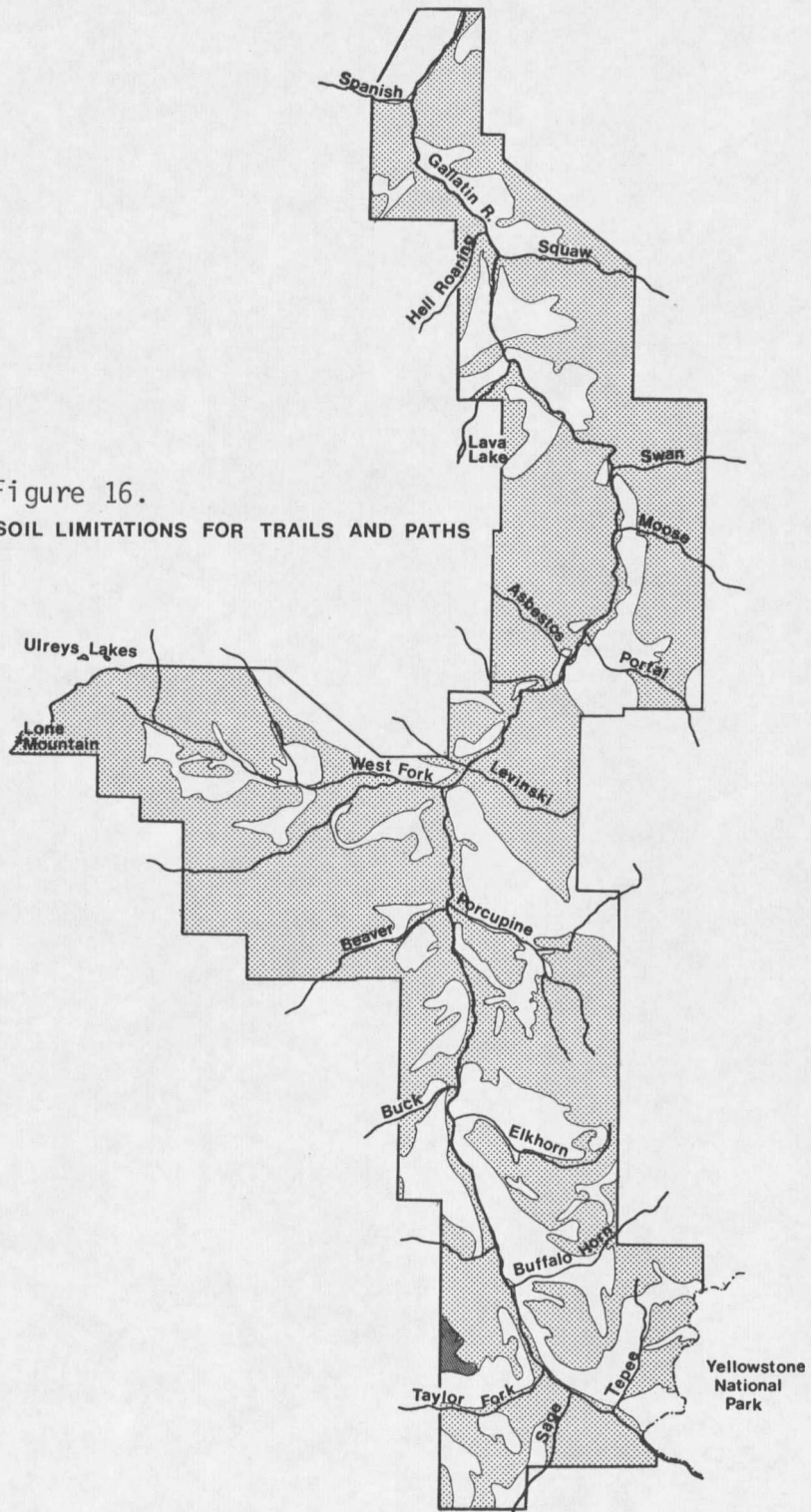
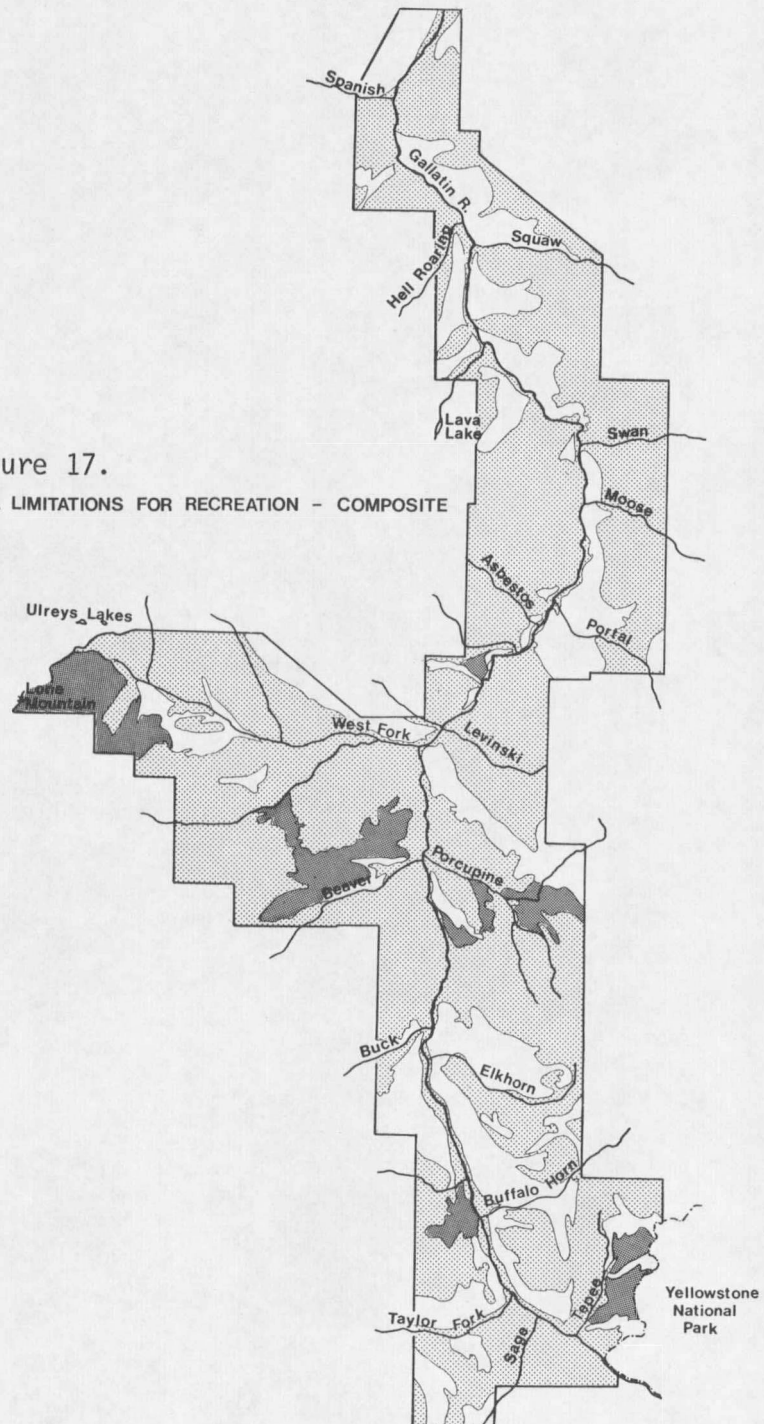


Figure 17.

SOIL LIMITATIONS FOR RECREATION - COMPOSITE



map was created. A computer printed map in which all sections of the area surveyed were subdivided into 1/16 of a section or 40 acre blocks at a scale of 1 inch = 1 mile was made. This computer map subsequently served as a base map for recording slope classifications of each 40 acre block according to the steepness of the majority of the slopes within the block. Seven slope classification categories were used:

- a. 0-2% slope,
- b. 2-5% slope,
- c. 5-9% slope,
- d. 9-15% slope,
- e. 15-30% slope,
- f. 30-60% slope,
- g. > 60% slope.

The subdivided computer-printed map was lain over 15 minute U.S.G.S. quadrangle sheets for the appropriate areas. Measuring rules were used to determine the distance between topographic lines which in turn was mathematically converted to one of the seven slope classification categories, a. to g., by consideration of the map scale and contour interval distance. For example: 40 foot contour intervals measuring 1/50 of an inch apart on a 1:63,500 scale map are $(1/50 \times 63,500) \div 12 \approx 105$ feet apart. Therefore the slope is $(40/105) (100) \approx 38$ per cent, which would place it in the f. classification.

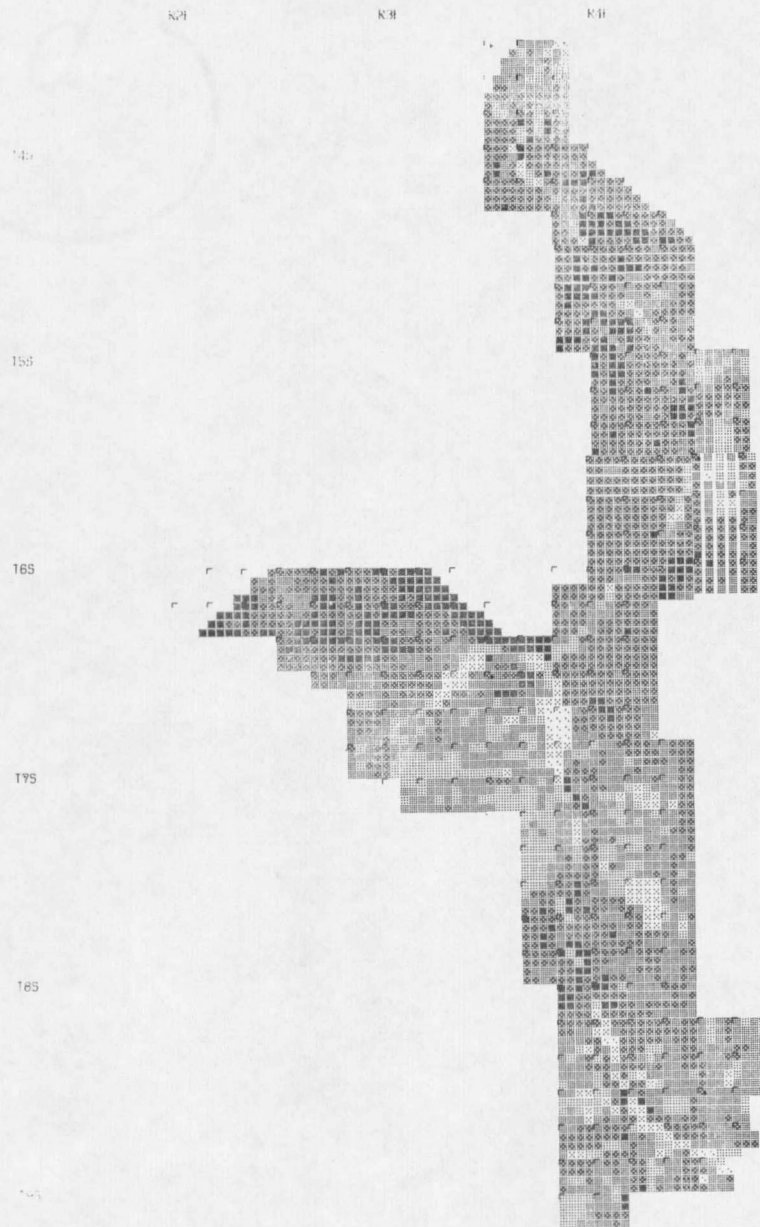
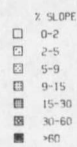


Figure 18.
Computerized
Slope
Classification



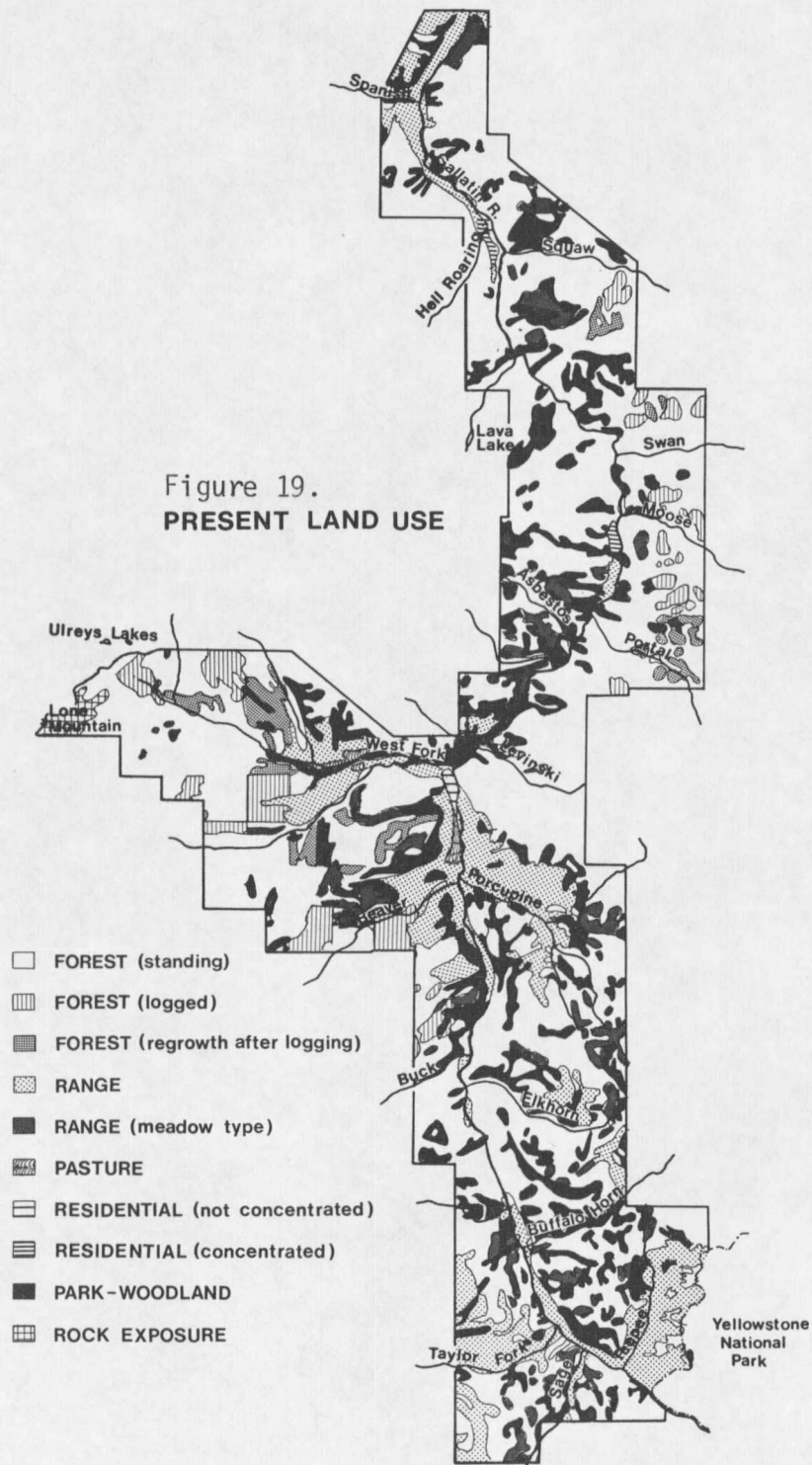
The appropriately coded letters, a. to g., were placed in each block as the predominant slope in that block was determined. Subsequently, computer programmed manipulations converted the coded letters to a density symbol which then appeared in the block in place of the letter on the computer printed map. Steep slopes were given the greatest density and the least sloping area the least density. The original computer printed slope map is on file at the Department of Plant and Soil Science, Montana State University, Bozeman, Montana. Computer programming services were carried out by employees of the Systems Group of the National Science Foundation supported Gallatin Canyon study team under the direction of Dr. R. Emerson.

A reduced copy of the original slope classification map which measures 34 inches long and 16 inches wide appears on page 76. A transparent copy of the small scale map shown on page 76 was also constructed to be used as an overlay for the maps shown on pages 65 to 74.

Present Land Use Survey

A present land use survey was conducted for the same area covered by the soil survey in the Canyon. Land use was classified and mapped at a scale of 1 inch = 1 mile using the following units:

Figure 19.
PRESENT LAND USE



F₁--standing forest,

F₂--logged forest (ex.--slash or dozer-piled),

F₃--immature forest (young growth),

R --rangeland,

Rm--range (alpine meadows),

P --pasture (managed),

Ac--residential area (concentrated--Beckman Flats),

An--residential area (not concentrated--Buck's T4 area),

W --park-woodland areas.

A reduced copy of this map appears on page 78. It is important to bear in mind that some of the units such as F₁, F₂ and An are subject to rapid change and this map represents the land use conditions in the spring of 1971. The original map indicated the presence of rock slides, talus slopes and cliff areas by appropriate spot symbols. The small scale, 1 inch = 4.36 miles, of the present land use map shown on page 78 precludes the inclusion of this information.

As part of the present land use survey 113 recreation sites were examined and plotted on a mylar overlay of the basic land use map. These areas are accessible by vehicle and as a general rule are used enough during the year to show some physical evidence of use. Each site was described as to type of activity, size, general conditions, facilities and whether the area was officially planned by some responsible agency or if it appeared to have become established by impromptu

action. This information, site locations and the original present land use map showing rock outcrops are available at the Department of Plant and Soil Science, Montana State University, Bozeman, Montana.

Detailed Soil Investigations

Four sites were chosen on which to carry out more detailed soil investigations for the purpose of checking the accuracy of the interpretations which were based solely on experience and field observation. Accordingly, sites were chosen which would represent slight, moderate and severe limitations for residential development. Use factors of significance to residential development are foundation, septic tank filter fields, roads and streets and lawns and landscaping. Soil and site factors pertinent to these uses are slope, permeability, flooding hazard, depth to bedrock, depth to seasonal high water table, susceptibility to frost heave, shrink-swell potential, compaction characteristics, bearing strength and stoniness.

Michelson loam interpretations indicate it to be a soil constituting relatively slight limitations for residential development. Loberg series represents moderate limitations and Kissick series poses severe hazards to residential development. Figure 20, page 81 shows the landscapes which are typical of those on which these three soils are located. Kissick soils occur in the flat, level foreground, Michelson soils are present on the sage covered benches in the middle



Figure 20. Typical Landscape Positions For Kissick-
foreground, Michelson-terraces, and Loberg
Soils-forested uplands, in the Gallatin
Canyon.



Figure 21. Michelson Series Exposure Revealing Cobbly
Texture of a Soil Well-Suited for Residential
Development.

ground and Loberg soils are typically found in the steeper, forested slopes of the background. Figure 21, page 82, shows a cut in the bench referred to in Figure 20. The cobbly nature of the exposed Michelson soil is evident. In addition to Michelson, Loberg and Kissick soils, one other soil which is unnamed and not described because of its inextensive occurrence was examined because of the hazard which its observed properties appeared to present to land development. It will be referred to as Michener, although the reader is cautioned that this is a local geographic name and has no official soil related status outside of its use in this thesis.

Thirteen percolation tests were performed according to the Montana State Department of Health recommended procedures (71). Soil samples were screened through 1.5 inch mesh standard sieves at the site and subsequently screened through 2 m.m. mesh sieves prior to laboratory mechanical analysis (67). The site location, conditions, percolation results and textural analysis are shown below. The field photo number on which each site appears is also indicated.

Table 5 . Textural Analysis, Percolation Test Results and Site Conditions for Michelson Series.

Site: 1320 feet west, 4300 feet north of the S.E. corner of section 8, R4E, T7S, Gallatin County, Montana. The vegetation consisted of unidentified grasses and sagebrush on a three per cent slope in an exposed location. The area was well drained, not subject to flooding and was being used as range for domestic cattle. The site appears on photo E10-10-271.

Percolation Test Results

Test Hole	Rate of Waterfall
A	4.5 inches/30 minutes
B	6.0 inches/30 minutes
C	1.6 inches/30 minutes

Textural Analysis*

Sample Depth	Per Cent Sand	Per Cent Silt	Per Cent Clay	U.S.D.A. Texture
9-13 inches	36	44	20	loam
25 inches	32	46	22	loam
52 inches	84	12	4	loamy sand

*All textures shown are based on the material smaller than 2 m.m. in diameter and all the textural classifications for Michelson series would be preceded by gravelly and cobbly. Below the 10 inch depth,

30 to 80 per cent by volume of the typical Michelson profile is gravel and cobbles; see the Michelson Series description in the Appendix, page 158.

Table 6 . Textural Analysis, Percolation Test Results and Site Conditions for Loberg Series.

Site: 660 feet west, 990 feet north of the S.E. corner of section 6, R4E, T7S, Gallatin County, Montana. The vegetation consisted of Lodgepole pine with an understory of unidentified grasses and shrubs, on an 8 per cent slope with a northeast aspect. The area was well drained, did not appear subject to floods and was being used for timber production and grazing for domestic livestock. This site appears on photo E10-12-63.

Percolation Test Results

Test Hole	Rate of Waterfall
A	1.37 inches/30 minutes
B	0.75 inches/30 minutes
C	0.50 inches/30 minutes

Textural Analysis

Sample Depth	Per Cent Sand	Per Cent Silt	Per Cent Clay	U.S.D.A. Texture
16 inches	44	38	18	loam

A description of a representative Loberg profile is contained in the Appendix, page 162.

Table 7. Textural Analysis, Percolation Test Results and Site Conditions for Kissick Series.

Site: 1072 feet north, 10 feet west of the S.E. corner of section 8, R4E, T7S, Gallatin County, Montana. This site is on a level stream terrace but is well drained and does not appear to be subject to frequent flooding. The area is used as pasture and the vegetation is domestic grass. This site appears on photo E10-10-271.

Percolation Results

Test Hole	Rate of Waterfall
A	3.0 inches/30 minutes
B	2.0 inches/30 minutes
C	1.6 inches/30 minutes
D	2.5 inches/30 minutes

Textural Analysis

Sample Depth	Per Cent Sand	Per Cent Silt	Per Cent Clay	U.S.D.A. Texture
16-20 inches	40	32	28	clay loam
34 inches	52	32	16	loam

Soil samples were also collected from the Kissick benchmark site which is described in the Appendix, page 165. Mechanical analysis performed on samples from the 22 and 35 inch depths produced U.S.D.A. textures of clay loam and loam respectively. The clay content in this profile at 36 per cent and 22 per cent respectively was higher than at the percolation test site.

Table 8. Textural Analysis, Percolation Test Results and Site Conditions for Michener.*

Site: 2970 feet west, 2310 feet north of the S.E. corner of section 7; R4E, T7S, Gallatin County, Montana. This site, located in an area of previous logging was vegetated by unidentified grasses, shrubs and incipient volunteer growth of coniferous species. The site was well drained, not subject to flooding and on a 4 per cent slope with north-east aspect. This site appears on photo E10-10-63.

Percolation Results

Test Hole	Rate of Waterfall
A	.37 inches/30 minutes
B	.45 inches/30 minutes
C	.40 inches/30 minutes

Textural Analysis

Sample Depth	Per Cent Sand	Per Cent Silt	Per Cent Clay	U.S.D.A. Texture
24 inches	36	42	22	loam
48 inches	34	44	22	loam

*Michener is not an established soil series and has no meaning outside of the context of this thesis.

An Economic Investigation of Development in Locations

Characterized by Soil and Associated Natural Resource Hazards

An investigation of costs incurred when land use change occurred in areas where serious soil and/or associated natural limitations for the development were present was carried out in the Bozeman vicinity. Private, public and commercial situations were examined to obtain those increased costs which are attributable to the site hazard. These are costs which, either expected or unanticipated, did and/or continue to occur as a result of the site condition and are separable from normal costs which would exist without the presence of the limitation. In the following description of the situations investigated, the site conditions and the required design are described in addition to the increased costs of overcoming the particular hazard.

Case 1. Public street--residential use.

Streets designed for and built on Bozeman silt loam require greater depth of road bed preparation than do streets for identical purposes on Beaverton gravelly loam. The difference in texture of the soils is demonstrated by comparing the classification of Bozeman silt loam shown in Table 9, page 89, with the textural classification of Beaverton gravelly loam shown in Table 10, page 90.

Table 9. Bozeman Silt Loam--Textural Classification

Horizon	Depth (inches)	U.S.D.A.	A.A.S.H.O. (1)	Unified (2)
A ₁₁	0-4	Sil	A-4	ML
A ₁₂	4-8	SiCl	A-7	CL
B ₁	8-13	SiCl	A-7	CL
B ₂₁₊	13-20	SiCl	A-7	CL
B ₂₂₊	20-28	SiCl	A-7	CL
C _{1ca}	28-48	Sil	A-4	ML
C ₂	48-64	Sil	A-4	ML

(1) A.A.S.H.O. soil classification system is used by the American Association of State Highway Officials.

(2) Unified soil classification system is used by the United States Corps of Engineers and the United States Bureau of Reclamation.

Table 10. Beaverton Gravelly Loam--Textural Classification.

Horizon	Depth (inches)	U.S.D.A.	A.A.S.H.O.	Unified
A ₁	0-6	G1	A-1	GW-GP
B	6-12	G1 (very)	A-1	GW-GP
C	12+	G & S	A-1	GW-GP

Typical sections for a residential street on Bozeman silt loam and Beaverton gravelly loam are shown in Figure 22, page 91. The cost of building one mile of 38.5 foot wide street as pictured in Figure 22 is shown in Table 11, page 91.

The difference in capital investment in the streets which are designed to provide the same service, require similar maintenance and both wear out in approximately 30 years is \$36,137 more for the street on Bozeman silt loam as opposed to the Beaverton gravelly loam. When amortized for 20 years at a Special Improvement District bond interest rate of 5.5 per cent (31), the total increased cost of the street on Bozeman silt loam is \$60,600 (1).

Figure 22. Typical Residential Street Cross Section For:

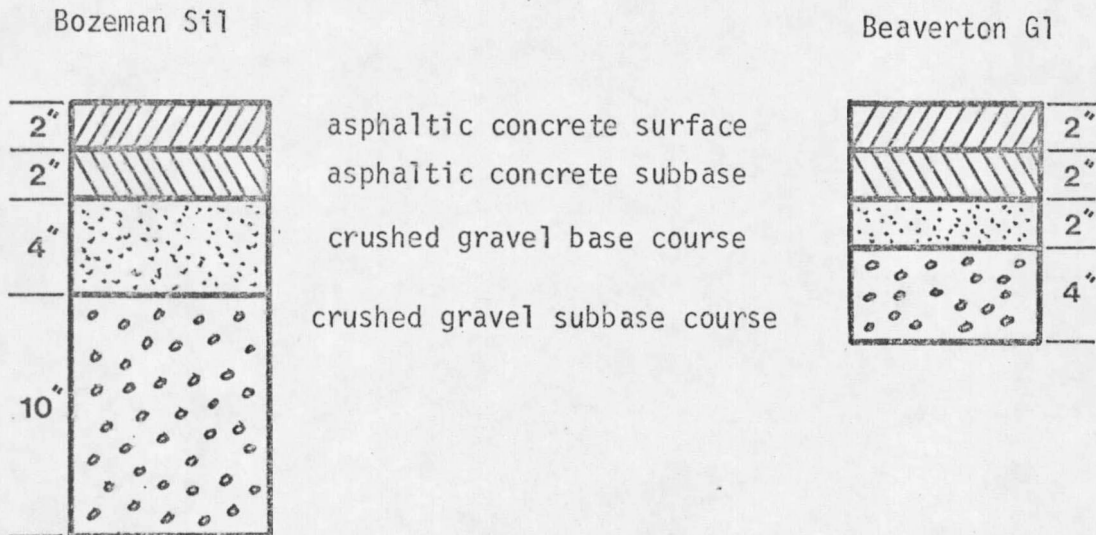


Table 11. Cost of Constructing One Mile of Residential Street
38.5 Feet Wide on:

Item	Bozeman Sil (dollars)	Beaverton G1 (dollars)
Excavation	13,552	7,526
Subbase and base course gravel	52,697	22,586
Asphaltic subbase	23,033	23,033
Asphaltic surface	<u>27,104</u>	<u>27,104</u>
Total	116,391	80,254

Case 2. Commercial development--septic tank drain field and campground road system.

Development of a suitable absorption field for a 2600 gallon campground septic system and road network on Gallatin silt loam swampy phase with high water table necessitates expensive design and upkeep. The water table at this site is commonly within 12 inches of the soil surface for the spring and summer months. An above-ground septic tank absorption field of sophisticated design is required (75). Gallatin silt loam swampy phase has low trafficability because of its low load bearing capacity and consequently poses problems for unimproved roadways.

The above-ground absorption field required \$2000 for materials and \$1000 in labour. This does not represent a realistic cost because it was constructed by the owner whose labour charge is not included. The cost of a similar set up by commercial contract would undoubtedly be much higher. Attempts to establish a grassed ground cover over the absorption field have failed for unknown reasons for two seasons.

The road system initially cost \$2000 for materials and \$500 for labour and equipment charges. Annual replacement of subsided gravel costs \$450.

An initial capital investment of \$5500 to overcome soil and high water table limitations, when amortized at 8 per cent for twenty years amounts to \$11,220 (1). At 6 per cent the total would be \$9,647 (1).

A seven year annually reoccurring payment of \$450 amounts to \$4015 (34).

Case 3. Commercial development--basement waterproofing, sump pump and subbasement drainage system.

Construction of a bank building of approximately 875 square foot floor space in an area of high water table necessitated subterranean waterproofing, drainage systems, a sump pump installation and difficult excavation and foundation construction. The soil texture and structure did not present a problem but a basement extending 10 feet below the soil surface in an area where irrigation ditch flows raise the water table to within 36 inches of the soil surface for the months of mid-May to mid-September required unexpected expenditures.

During initial construction, revelation of the extent of the problem necessitated design changes in the building which added \$1850 to the cost. These additions included extensive foundation sealer, interior water plug, subterranean drainage systems and a sump pump to discharge water which is drained from below the floor at times of high water table. As construction proceeded however, unexpected costs arose from the high water table problem. Pumping, equipment and enlarged excavation to prevent dangerous sloughing increased construction costs \$1650. Thus the total increased capital investment became \$3500. When amortized at 8 per cent for 20 years the cost becomes \$7140 (1).

Continuous operation of a $\frac{1}{2}$ h.p., 115 volt sump pump motor for one month or 720 hours costs \$9.04 (44). Annual costs of pumping at this bank for four months would be approximately \$36. Over a period of 20 years at 8 per cent, this amounts to \$1648 (34).

Case 4. Private home--septic tank drain field in an area of steep slope and close proximity to a creek.

Construction of a home on a slope of about 25 per cent which extends to a creek bank created unique problems in locating a suitable septic tank drain field.

The septic tank is buried adjacent to the home in fill material which was also required for support of the dwelling. Effluent from the tank travels via a buried pipe down the slope, across the creek and continues on to the site of a drain field which is approximately 300 feet from the septic tank. Flow to the drain field is dependent upon gravitational forces and hydrostatic pressure from the elevated tank which is approximately 50 feet higher in elevation than the drain field. Approximately 30 feet of the pipe is exposed at the point of creek crossing. Here it will be wrapped with electric heat tape and insulated to prevent freezing in the winter.

Total cost of the installation was \$1416. A 1000 gallon capacity typical septic tank installation for a residence of this size would cost \$600 if no problems or hazards were encountered (16) (22) (29).

Therefore the total increased capital cost is \$816, which if amortized at 8 per cent for 25 years is equal to \$1907 (1).

Case 5. Semi-private development--church constructed in an area of high water table on soils of poor load bearing capacity.

A Bozeman area church constructed on Gallatin silt loam swampy phase soils required extensive foundation support. The construction of a basement was precluded by the high water table. Drainage and maintenance of a usable parking lot on soils of low trafficability has been problematic.

Seventy creosoted piles, pile caps, concrete grade and span beams and associated labour increased the construction cost by \$11,700. Drainage and original development of the parking lot cost \$2013 and subsequent additions of gravel to maintain the lot have cost \$407.

The building loan is amortized on two repayment schedules, each sharing 50 per cent of the cost over a 25 year planning period. At an interest rate of 5 per cent, \$5850 results in a \$10,369 payment, and the other \$5850 at 8 per cent amounts to \$13,545. Therefore the total cost of overcoming the soil limitation for the building is \$23,914. In the first three years, \$2420 has been spent on the gravelled parking lot and there is evidence at this time that continued expense will be required to maintain its present condition.

Case 6. Private residence--septic tank drain field in area of high water table.

Reconstruction of a septic tank drain field in an area of high water table where the previous system had failed necessitated the excavation of original soil materials which were considered to be unsuitable for proper absorption field operation. In addition, a semi-elevated drain field was required in order to comply with state sanitation laws in this area where the water table is commonly three feet below the soil surface (71). This in turn necessitated an effluent holding tank and a submersible sump pump in order to transfer the septic tank effluent to the elevated distribution lines.

Materials cost \$699 and labour and equipment operation added \$1681 to result in a total cost of \$2380. When amortized at 8 per cent for 25 years this represents a cost of \$5563 (1). A typical installation where no site problems are encountered, with a \$600 initial cost would have totaled to \$1627 under the same amortization conditions (1).

Case 7. Private residence--reconstruction of a drain field in order to comply with Montana State Department of Health streambank setback regulations.

Pollution of a stream by an improperly operating septic system necessitated the construction of an excavated and semi-elevated

absorption field. The presence of a periodically high water table and the close proximity of the dwelling to the stream--approximately 5 feet, necessitated a holding tank and submersible sump pump in order to force the septic tank effluent to the elevated distribution field located 100 feet from the stream.

Total cost of materials amounted to \$238 and labour and equipment operation another \$213. Therefore a total cost of \$451 was incurred to replace a drain field which because a septic system was originally established too close to a public waterway in an area of high water table had become a public health hazard.

Case 8. Private residence--septic system backup into home because of rising water table.

The location of an absorption field in a flood plain which experiences high water table in the spring has resulted in ground water entering the perforated drain field lines, flooding the septic tank and subsequently overflowing a basement stool which is located at an elevation below the spring-time level of the local water table.

Installation of a sealed holding tank and a pump which forces effluent through the perforated distribution pipe during times of high water has stopped the basement stool from overflowing. The total cost of installing this set up in 1968 was \$420. At 1972 prices it would cost \$600. In 1971 the pump burned out and was replaced at a

cost of \$97.

V. DISCUSSION

Use of Soil and Associated Natural Resource Interpretations

Land use information is of interest to all planners and, depending on its quality, can greatly influence decisions affecting the future of large areas of land. Land use is no less important to individuals because its misuse can drastically alter the present and future quality of life. To be effective however, the information must be used; but to be of maximum use it must be accurate, easily understood, meaningful, economically produced and readily available. The inevitable changes in land use which are predicted for Gallatin County in foregoing sections were already occurring and it was imperative to assess the applicability of this research objective to provide information facilitating enlightened land use planning decisions.

Public interaction for the purposes of exposition, explanation, discussion, criticism and feedback have been actively pursued throughout the whole of the research undertaking. County commissioners, planning boards, private citizens, students, architects, professional planners, farmers, realtors and educators representing a broad spectrum of political, social, educational and economic characteristics have been consulted to provide direction for this endeavour. More than 45

presentations have been made to such people with over 1500 total contacts being made. Assessment of such scrutiny and reaction by the public has provided philosophic guidance for effort emphasis in presentations and future undertakings.

While the colour-coded soil limitation maps appear to be readily understood and most people have relatively few problems in recognizing the results of lack of attention to resource hazards, there is a considerable lack of knowledge about what actually causes such situations --for example, why septic tanks won't work properly on expandible clay soils. Nearly all discussants were anxious to have access to information which would enable them to recognize the existence of hazardous situations, help them avoid expense and assist them in knowledgeably participating in the planned growth of their community. The implication is that in addition to resource interpretations which facilitate general planning and stimulate an appreciation for resource use analysis, there is a need to provide more detailed information which is useful for on-site preliminary investigations by individuals engaging in resource development and management. This observation forcefully supports one of the basic research assumptions that nonprofessional decision makers would use easily understood resource planning interpretations if the pertinent information was properly presented.

While there was always a general agreement at the "overlay presentations" that soils in fact do affect design and engineering

requirements of development and nonwasteful land use change, there were always the questions of "how much?". "What is the practical or real difference between slight, moderate or severe land use limitations? Perhaps, the distinction is so subtle that it is inconsequential!" It was in response to this type of public reaction to the interpretations that a need to be more explicit or relevant was recognized. In order to have a significant impact in terms of quantitative description, the information had to be presented in a context embodying universally appreciated parameters. There are few things more broadly understood and comparable than monetary units, and so this was the approach chosen to achieve a forceful demonstration of the degree of difficulty in overcoming soil and associated natural resource development hazards.

By having carried out pertinent examinations of selected soils within the study area in readily observable sites it is now possible to present along with the general soil interpretations, an exposition of some major on-site resource character considerations. An economic analysis of real-life situations occurring in the Gallatin Valley provides poignant examples of the effects of resource hazards on design and cost of overcoming limitations. Prior to discussing the incorporation of this information in an effective presentation, it is important to be cognizant of the technical or tangible significance of these factors before pertinent and meaningful statements can be made in the more generalized context of a public presentation.

While the soil and associated resource factors which affect land use planning and development are listed in both the Explanation of Table 1 on page 129 of the Appendix and the Definition of Selected Uses in the General Soils Map Report for the Gallatin Canyon, there is no explicitly detailed explanation of just which site characteristics are responsible for these properties. There is no intention to engage in an exhaustive dissertation on all possible site and soil properties or the degree of limitation which the presence or intensity of expression each may constitute. This is adequately explained in the Soil Conservation Service Guide For Interpreting Engineering Uses of Soils (33). However, of all the factors therein described, several are conspicuously prevalent in their influence on nonfarm development hazards in Gallatin County. These are texture, slope and landscape position characteristics. These three factors were the foremost considerations in choosing sites on which to carry out detailed soil and economic analysis research for the purpose of strengthening the concept of applying resource interpretations to land use planning.

Important Land Use Implications Revealed

by Detailed Soil Investigations

Texture, slope and landscape position are the most important soil and site factors which in variable combinations create different suitabilities for different uses. Texture, for example, has a direct

relationship on load bearing capacity, susceptibility to frost heave, shrink-swell potential and permeability. These properties have great importance for design, cost, maintenance and performance of foundations, roads, streets, absorption fields and trafficability. Landscape position commonly reveals susceptibility to seepage, springs, flooding and high water table. Slope in combination with texture and landscape position has extensive influence upon erosion, stability, access limitation and ease of activity performance.

The Michelson soil, because of its location on the high stream terraces is not subject to flooding or high water table hazard. The very rapid percolation rate indicates that septic tank absorption fields would perform very well. There could be concern that the gravelly nature of most of the Michelson soils would not provide adequate filtering action to purify the septic effluents. This may be a consideration but there are probably enough fines in the profile, the upward movement of liquid material in this dry region would be substantial, and the water table being more than 10 feet below the soil surface would probably not be contaminated. Research carried out in the vicinity by Keppner supports such a contention (30). On the steeply sloping terrace faces however, problems could be encountered with septic absorption field installations. Therefore such developments should be restricted to the terrace top areas.

The gravelly and cobbly nature of the Michelson profile makes it an ideal site for foundation construction. However, areas of relatively stone-free materials could be encountered. Here the loam textured material would classify as an A.A.S.H.O. A-4 to A-6, depending on the silt vs. clay content, and as such would constitute moderate to severe problems for flexible pavement, roads and parking areas. Where such conditions are encountered, in order to avoid the problems of low load bearing capacity and the potential for frost damage, excavation and extensive road bed preparation such as that described for Bozeman silt loam would be required. More commonly however, the gravelly and cobbly material will prevail and a construction situation similar to that for Beaverton gravelly loam will exist.

The Kissick series in contrast has very serious development limitations because of the hazards inherent in the high clay content. These soils, although they are level, well drained and not subject to frequent flooding, are characterized by a very high shrink-swell potential. When dry, cracks of up to one inch wide develop at the surface and evidence of such cracking can be detected to depths of at least three feet in the soil. This is primarily responsible for the unexpectedly high percolation rates reported. The percolation tests were performed in late August when these soils were very dry and extensively cracked. Test hole C was soaked much longer than the others in an attempt to approximate spring conditions, with the result being that the rate of

percolation decreased as the soil began to swell. Test hole C was also located in a profile more typical of the clay content represented by the benchmark site than were test holes A, B and D where the 34 inch depth texture was notably lower in clay content.

Under spring moisture conditions the Kissick soils swell and show no evidence of cracking. Percolation tests performed at this time would more likely resemble those results which are shown for Michelson. An additional consideration in the use of Kissick soil for septic systems is that the introduction of sodium into the profile would cause particle dispersion, negligible hydraulic conductivity and eventual failure of the system. The use of a water softener would definitely be precluded and there is some chance that normal household effluents would eventually lead to blockage.

The Kissick soils, which have an A.A.S.H.O. rating of A-7, have poor trafficability when wet because of their very sticky and very plastic nature. Shrinking and swelling which occurs under varying moisture contents and is apparent in the slickensides in the profile would cause cracking of conventional sidewalks, patios, garage floors and driveways. Extensive and costly excavation and road bed preparation would be required in order to have stable roads, streets and parking areas.

Development on Loberg soils would not be as difficult or as costly as on Kissick soils but it would undoubtedly be more problematic than

on Michelson soils. Slope is a factor which is a significant limitation on almost all Loberg soils in that few occur on slopes of less than 10 per cent. Percolation results on a Loberg soil which is typically loam to sandy loam in texture with 35 to 70 per cent coarse fragments show very low permeability at the site tested. The soils at this site were moist but not saturated at the time of the test.

Because of the high silt content, Loberg soils are susceptible to frost heave and consequently would require extensive foundation preparation for any installations which would be damaged by such movements. Loberg soils also appeared to be prone to slumping and instability.

This probably occurs when unfavourable hydrologic conditions combine with slope and physical disturbances such as road building to precipitate mass movement.

Michener soil was investigated because of the readily observable hazards which it presented to development and manipulation. At a point where a logging road crossed this soil, the physical evidence of the great difficulty with which vehicles traversed the area was apparent. The road was deeply rutted and eroded, and under wet conditions virtually impassable because of the highly plastic and sticky nature of the moistened soil. The high silt and clay content would rate this soil an A-7 A.A.S.H.O. classification and the very low rate of permeability would preclude its use for septic absorption fields.

These are typical technical and physical features which require expensive design and construction to overcome in development. A small amount of on-site inspection would enable a nonprofessional person who knew what to look for to make at least a preliminary estimation of the problems which might be encountered with certain proposed developments. By exposing a soil profile to about four feet in depth, the soil descriptions and maps in the interpretation publications could be used to identify the soil at the site. Then by considering the factors described above and consulting the limiting soil properties and hazards and relating them to interpretations for selected uses contained in the Soil Interpretations for either the Gallatin Valley or the Gallatin Canyon, the investigator would be better informed as to the nature of problems which may exist. Any doubtful or questionable features should be discussed with capable people or firms offering soil consultation and development services.

Too frequently however, especially with private individuals, little or no investigation is performed with the unfortunate result being unexpected damage and costly repairs. Larger organizations such as construction firms make use of such information when designing and bidding on proposed developments. Although these people are usually aware of site problems and can design to minimize detrimental effects, it is unfortunate that a poorly informed society is unable to constructively question the propriety of locating high-cost, taxation-funded

developments in locations poorly suited for them. If the public was able to knowledgeably scrutinize such undertakings, subsequent debate on alternatives and trade-offs would at least provide taxpayers with some influence over resource allocation and development undertaken at public expense. This point was revealed in the economic analysis of some situations investigated in the Bozeman area.

Soil and Associated Natural Resource Limitations
as Cost Increasing Factors

The investigation of eight cases where site limitations created development complications is evidence of the fact that it is expensive to ignore or to contradict nature. Texture, slope and landscape position have all exerted their influence in increasing costs. Locating on steep slopes, too close to creeks and in areas of high water table require unique and expensive septic tank absorption fields. Locating structures and roads on unstable or silty soils necessitates very expensive construction and frequent compromise in utility. In almost all cases, the costs, worry and maintenance attention continue after the initial effort theoretically nullified the hazard. Whether these costs are large or small is completely dependent upon the individual's point of view--what is burdening to one is inconsequential to another. In some cases the developers were well aware of the implications and after considering the alternatives decided that the trade-offs were in

favour of the development. Such occurrences are less common than the situations where unsuspecting developers are faced with unanticipated problems which frequently result in spiralling costs or inadequate short term solutions which continue to erode the quality of life for those who have to live in the presence of the condition. It is not unusual for situations to develop, such as that described in Case 8, where the solution may constitute a hazard for other people--example: forcing septic effluent directly into the ground water.

Many discussants are unaware of all the costs which they directly and indirectly incur for both themselves and the populace by violating natural resource constraints. The cost of a sophisticated elevated absorption field does not cease with its construction. If financed under a typical home improvement loan, the total cost increases dramatically. If the development is paid for in cash, a loss of opportunity investment is a rightful charge to the overall cost. Residents of flood plains are frequently in the news regarding the plight of their watery conditions. A small flood on the West Gallatin River in the spring of 1970 destroyed land worth \$34,000, structures worth \$78,330 and crops worth \$32,000. This represents approximately 1/3 to 1/2 of the people involved (65). These actual losses are only part of the cost because they lead to much greater expenditures which attempt to protect people from their self-imposed disasters. The Gallatin County Commissioners have spent \$10,000 on dikes and anticipate

spending \$100,000 for rip-rap. The man-hours spent by the city of Bozeman in flood control of Sourdough Creek has risen from 1207 in 1964 to 2031 in 1970 (36). Thousands of dollars were spent to repair a dike which burst along the Madison River in late winter of 1972 and imperiled lives and property near Three Forks. Most of the people involved, while announcing their intention to remain in the area demanded public expenditures to alleviate their condition. In this way many of the costs created by lack of attention to resource situations on the part of individuals become general costs which the public bears.

Individuals insisting on developing in poor sites incur direct costs for themselves and indirect costs for the tax-paying public by demanding public facilities which are correspondingly more expensive to install. Bozeman residents complain about the poor condition of Eighth Avenue South but apparently are unaware that they are continuing to demand and support new roads and streets in areas of equally hazardous conditions which will require very costly design if they insist on a road of higher quality than Eighth Avenue. This is apparent in that much of Gallatin County's real estate activity is occurring in the area south and west of Bozeman on soils of low load bearing capacity and seasonally high water tables. Reference to the soil limitation map for residential development on page 57 indicates that this area is poorly suited to such developments whereas the Beaverton gravelly loam soils of the Belgrade area have few limitations. The cropping map in contrast

indicates the Bozeman area to be highly suitable for cropping but the Belgrade area soils to have severe limitations for agriculture.

Development proceeds south and west of Bozeman however, because in the absence of any land use controls, people will automatically be attracted to flat, fertile farmland closer to the mountains and farther away from the airport. By extracting from production some of the best irrigated agricultural soils which were brought into use at high cost, other poorer areas may be substituted at higher operating costs, lower return and overall decline in efficient use of energy expenditures. Loss of irrigated soils jeopardizes the perennial economic stability of the very important agricultural industry in Gallatin County. On the other hand it is difficult to argue for the protection of dryland agricultural properties when Gallatin County farmers were paid \$1,477,457 in 1971 to not grow crops on 21,326 acres of farmland (84). It is even more difficult to convince a landowner that he should forego a potential financial windfall by voluntarily withholding the sale of his property for nonfarm uses because it is poorly suited for the proposed development. Studies have shown however that small towns rarely benefit by nonfarm development and that only agricultural enterprises have a net positive economic result (23).

An economic analysis of resource use is a vastly complex subject and it has not been the purpose of this research endeavour to expose more than some of the situations which Gallatin County residents

frequently ignore, much to their sorrow. The sole purpose has been to show that some consideration will reveal alternatives and if the presence of avoidable costs can be demonstrated, then both private and public planning agencies will be in a better position to execute more efficient decisions than they would be in the absence of the information.

Future Emphasis in Using Resource Interpretations

The constitution of the United States guarantees every American the right to life, liberty and the pursuit of happiness. In a society where individual deportment and private rights are highly cherished and vigorously protected, increasing population in conjunction with almost unlimited individual capabilities has resulted in many abuses of the nation's natural heritage. In the pursuit of life, liberty and happiness, many individuals have encroached upon the health, freedom and pleasure of others. These situations have given rise to an unprecedented concern for the individual's right to a quality environment and how public and private actions jeopardize that realization.

Our society, founded on free enterprise and participatory democracy, has always supported the philosophy that few things should be denied individuals if by legal manipulation of society's systems, these people could afford that which they sought after. In essence, if you can pay

for it, you can have it, and after you own it you can do what you want with it. Excessive abuse of this latter freedom has created serious infringement upon both public and private values and consequently, regulations concerning use were instituted--for example: air pollution regulations, zoning laws and speed limits. However, continued depletion of resources, increasing population and growing concern for the natural environment have given rise to widespread questioning of the moral right and long-term consequences of individuals luxuriously consuming and possessing resources simply because they can afford it. Perhaps many others or the well being of the nation's environment cannot afford it. In the process of evaluation of social mores, attitudes toward private and public use of unlimited resources are being formulated. The recent activity regarding county-wide planning for Gallatin County is an example.

The forces which fear encroachment upon private permissiveness are very strong in Gallatin County and have been successful in stymieing regional planning establishment. However, change of attitudes resulting from population replacement, education and increased evidence of undesirable developments will eventually support efforts for planned growth. When this occurs, the need for decision-making information will be even greater than it is at present.

The soils interpretation information, as it exists, lends itself very well to revelation of area suitability for residential construction,

preservation of open spaces, agricultural land protection priorities and interim flood plain identification. Further investigation and prediction refinements could facilitate knowledge for the protection and management of aquifers, important watersheds, recreation resources, game ranges and transportation routes. Research presently in progress to computerize soils and related data could be used to make predictive statements when inserted into appropriate regional models. This assumes however that equally important information on the other critical resources such as air, water, geology and vegetation will be available and that appropriate weighting, values and comparable parameters can be identified. This in itself is an intricately complex and relatively massive undertaking. Computer analysis and map-printing systems comparable to but much more sophisticated than the computerized slope map previously described could be used to interpret, predict and display with instructed objectivity that which we now attempt to do by manual labour. Simple manipulation of values and weighting systems could demonstrate the changes in predictive outcome resulting from different approaches to development. In this way priorities can be applied to alternatives, externalities can be experimentally internalized and rational decisions in harmony with identified social objectives could be facilitated.

In the final analysis however, human desires, values and needs will probably continue to determine the balance of trade-offs and

courses of action. By utilization of a systematic approach to resource development however, society will at least be capable of more knowledgeably influencing control of its destiny. While it is undoubtedly possible to physically achieve the foregoing which undeniably would be an ambitious and meritorious project, an equally important task must be successfully accomplished if the former is to be of any practical value. Efforts towards social motivation must necessarily establish a sense of need and desire to accomplish efficient resource use amongst the populace or the capability to execute it will be of little consequence.

In subsequent presentations of the soil and associated natural resource interpretations and development considerations, at least two major objectives should be pursued. These are to contact both those individuals who are convinced and those who are unconvinced that there is an urgent need to engage in more efficient resource allocation and regional planning.

Many convinced people need to become better equipped to engage in meaningful participation in the regional planning process. Enthusiasm and concern do not automatically guarantee understanding and accomplishment. In order to be effective in forming justified opinions and making objective decisions, participants in planned growth policy formulation must have pertinent facts. These facts must be presented in an appropriate language and context in order to assure their proper

assessment and inclusion in the decision-making process. Whether these planning participants are engaged in resource management activities as individuals on privately owned property or as public officials with a larger responsibility, they can utilize the soils and resource information both at a detailed scale or at the more generalized scale to plan development or management programs.

Unconvinced people need to be exposed to the merits and benefits of using resource interpretations to effect more efficient growth, both for individuals and society. Too frequently however, many people have no appreciation or concern for public values or long-term concepts of societal welfare. In such instances a successful appeal to individual benefits in the short-term may be achieved with the demonstration of cost enlargement resulting from contradiction of nature and physical constraints. This falls far short of the larger and more philosophic objective of regional approaches to land use policy but it cannot be rejected as being inconsequential, for all things start somewhere. It is also not impossible that such individuals, if they are favourably impressed by a sincere, simple and meaningful approach to land use will be motivated to consider themselves as leaders of change. They could become staunch supporters of innovative practices which preserve and enhance the Montana way of life.

It is important however to be acutely aware of the fact that soil and associated natural resources as discussed in this thesis are only a

small part of all the considerations necessary to achieving a comprehensive assessment of resource development priorities. Other physical and biological factors such as hydrology, climate, geology, vegetation, distance and elevation are no less important and in many cases undoubtedly of greater concern in decision making. Social and economic values are important inputs to resource allocation commitments and society's established support systems of transportation, services and communication are obviously another of the vital considerations in considering alternatives, identifying trade-offs and deciding priorities.

Future efforts should be exerted in contacting the public for further guidance in formulating regional planning research projects of societal relevance. If failure by default is to be averted, then one of the continuing objectives of this kind of research must be to get the results to the decision makers. At least one way to do this is through State Extension Service involvement in community development programs. Other appropriate outlets for distribution of such information are chambers of commerce, real estate agencies, contractors and builders associations, county commissioners and any other agencies which have some contact with the public. Researchers must be cognizant that information which is not readily available or appropriately advertised will be of little consequence in achieving a beneficial societal impact.

SUMMARY AND CONCLUSIONS

Trends in use of natural resources in United States and the State of Montana prognosticates the high values, both real and intangible which will be placed on western Montana's spectacular natural attributes. The increasing demand for quality outdoor recreation opportunities and development of cottages, second homes and recreation resorts has exposed the intensifying conflict between historic activities and the new priorities. Inadequate management, incompatible resource use practices, the threat of depletion or degradation of unique natural features and the growing concern for the state of environmental quality have all combined to reveal a desperate need for information which will facilitate effective land use planning decisions.

This need poses a direct challenge to the resource scientist to be innovative, accurate and pertinent in his research, analysis and reporting. To be useful, resource management information must be easily understood so it can and will be incorporated into the decision-making process by those examiners who are unable or unwilling to decipher and interpret uninteresting or complicated scientific data.

The unique bounty of high quality natural resources suitable for a large variety of outdoor recreation activities and a peaceful and attractive way of western life are attracting population growth and development to Gallatin County in proportions unequalled in Montana. Attempts to engage in regional planning have been sporadic and

uncoordinated, partly because of the lack of appreciation for the necessity of such actions on the part of local decision makers and the absence of pertinent information which could help facilitate a socially acceptable planning philosophy. It is well known that environmental quality and historic local customs are inevitably destroyed by over participation and disorganized development. Unfortunately however, unimaginative and traditional approaches to instituting planned growth policies have been pursued in this area where private rights, independence and rugged individualism are highly esteemed, and not surprisingly, have been rejected. An approach which appeals to a respect for the land, its resources and their combined productivity, both tangible and intangible, is more likely to be favourably received by individuals who value their natural heritage and self-directed destiny more than unjustified sacrifices for holistic philosophies.

The importance of soil and natural resources is readily recognized and appreciated in an agriculturally dominated community. Therefore an approach which emphasizes a "design with nature" in which careful attention is accorded soil and natural resource development hazards should have desirable acceptance.

Surveys for the purpose of inventorying basic resource factors preparatory to making land use suitability predictions were carried out for most of the county. Residential developments, agricultural land, recreation areas and wilderness components were all represented within

the survey boundaries. Soil interpretations for land use planning and development were determined by analyzing the resource information according to established guidelines. Up to twenty-two individual resource properties such as slope, seasonally high water table or poor load bearing capacity were used in rating individual soils as having slight, moderate or severe limitations for sixteen uses such as septic tank drain fields, recreation sites and roads and streets.

Individual colour-coded land use soil limitation maps were prepared on transparent mylar where slight, moderate and severe limitations for the particular use were geographically depicted in green, yellow and red colours. These maps have been used at presentations to over 1500 persons where various combinations of overlays are used to demonstrate a wide range of locational suitabilities for different kinds of development or land use. These maps are easily understood and were favourably received, even by self-proclaimed opponents to anything associated with planning.

The expression of a desire to know more about what constitutes a soil or site limitation and what that implies in terms of increased costs required to overcome the hazard was the basis for carrying out detailed site investigations. These detailed facts, when appropriately presented in conjunction with the concomitant economic information increases the credibility of the soil interpretations and lends support to the overall philosophy of the desirability of a land use policy

which "designs with nature."

A large part of the merit and potential success of a low-keyed, nonpartisan approach which emphasizes respect for and proper treatment of the land is that most individuals, irrespective of their attitudes regarding private values and public welfare, can identify potential benefits which they could experience by using this information. Any action towards more efficient resource utilization resulting from the use of this information, whether it be by an individual or a public body, justifies future engagement in similar activities pursuant to the identification of socially relevant problem-solving efforts to which the resource scientist can apply his expertise.

In conclusion, it can be succinctly stated that:

1. The increasing use of and concern for the natural heritage and outdoor environment of the nation has created a demand for information on which to base action programs designed to restore and maintain the quality and quantity of attributes and benefits derived from natural resources.
2. There is an urgency to convince disbelievers that it is imperative to engage in more efficient resource use and allocation in order to ensure the future well being of the nation and its people.
3. Soils and associated natural resource interpretations resulting from the research herein reported, when presented in an appropriately technical, adequately simple and economically meaningful language is

sufficiently comprehensible to effect a favourable reception and significant impact on 1. and 2. above. Such success is evidence of the proof of the hypothesis that soils and associated natural resources are important decision parameters in the regional planning process.

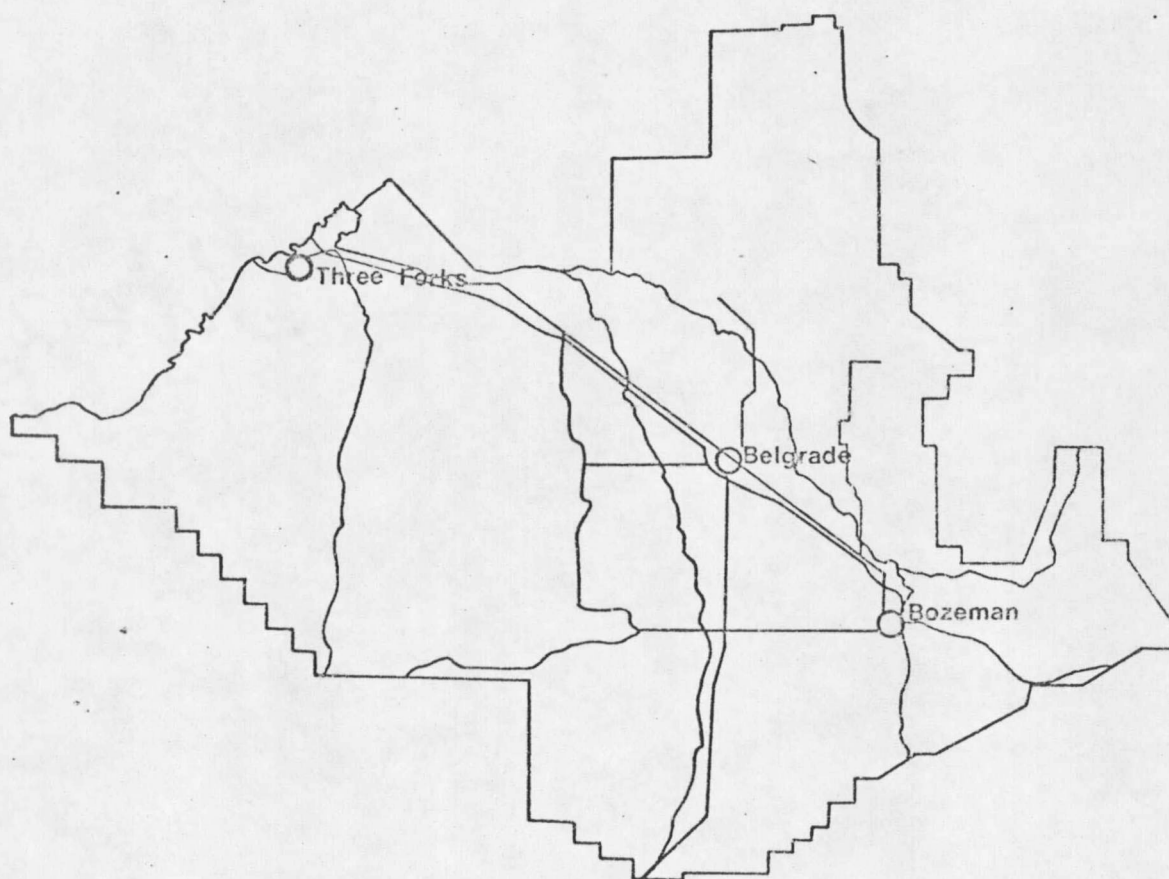
APPENDIX

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SOIL INTERPRETATIONS
FOR
LAND USE PLANNING AND DEVELOPMENT
IN THE
GALLATIN VALLEY AREA, MONTANA

-- A Preliminary Report --

August 1970



Montana Agricultural Experiment Station
Montana State University, Bozeman

U. S. Department of Agriculture
Soil Conservation Service

FOREWORD

These soil interpretations for land use planning and development were prepared at the request of the Gallatin County Commissioners and the Gallatin Valley Soil and Water Conservation District. The 1931 soil survey report and map attached to the back cover describe and delineate the wide variety of soils in the valley. Using this map as a base, local soil scientists and other specialists have combined their firsthand knowledge derived from years of field experience in the area and have taken into consideration the available laboratory data, engineering guides and current Montana Department of Health standards. Using this information, they have developed tables which indicate local soil limitations or suitabilities for cropping, road locations, urban development, waste disposal, recreation sites and other uses. These interpretations will not eliminate the need for on-site soil investigations for specific design and construction.

Soil survey information is basic to sound planning and development of our rural and urban land resources. Even though severe soil limitations can often be overcome through engineering and technology, it is our purpose to encourage careful consideration of all costs to developers, buyers and taxpayers before soils are put to uses which are not suited to their natural properties. Theoretically, any soil can be used for any purpose--practically, the costs may be too great.

CONTRIBUTORS

All who contributed their experience and expertise in preparing these interpretations cannot be acknowledged here. The following list of major contributors is provided to assist those who may wish to obtain additional information about the natural limitations and capabilities of Gallatin Valley Soils.

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EXPLANATION OF TABLE 1 - "Estimated Soil Limitations or Suitability
for Selected Uses."

The map symbols and names of soils given at the top of Table 1 are keyed to the attached soil survey report and map published in 1931. Soils are rated for each of 16 selected uses shown at the left of the table.

Soils rated as slight are relatively free of limitations or have limitations that are easily overcome. Soils rated as moderate have limitations that need to be recognized but can be overcome with good management and careful design. A severe rating indicates limitations that are difficult or costly to overcome. A severe rating does not mean the soil cannot be used for a specific use, but it means that careful planning and design and very good management are needed. In some cases, severe limitations are not economically feasible to correct.

Numbers following ratings of moderate and severe are keyed to 15 limiting properties listed on pages facing Table 1. These numbers identify the major properties which determine the limitations of a particular soil.

All interpretations are based on the upper 5 feet of soil material in its natural state unless otherwise noted. Geologic reports can be of benefit for evaluating material below five feet.

These interpretations are for general planning. All soil

differences which occur in the field cannot be shown on a general soil map. Therefore, on-site investigation is needed for specific design and construction.

Unlike modern soil surveys, the 1931 survey does not separate soil areas that are nearly level from those with steeper slopes. Thus, slope percentage must be measured in the field or obtained from topographic maps. Table 1 shows that Amsterdam silt loam, for example, has slight limitations for cropping; moderate limitations if slopes are 5 to 9% and severe limitations if slopes exceed 9%. Other soils such as Bridger stony loam, although they also occur on a variety of slopes, have other limitations such as extreme stoniness which override the problems of slope. Still, other soils such as the Beaverton series occur only on nearly level areas and therefore are not limited by the slope factor.

The 16 selected uses of soil and the properties considered important in evaluating soils for each use are given below:

Cropping is based on the capability of the soils, when properly managed, to sustain cropping without risks of serious soil damage. It is affected by factors such as soil texture, depth, permeability, available water holding capacity, flooding or ponding hazards, salinity and alkalinity, slopes and erosion hazard.

Road and Street Location is affected by depth to seasonal high water table, flooding hazard, load-bearing capacity, frost action

potential, stoniness, depth to bedrock and topography.

Foundations for Low Buildings with Basements are affected by soil properties and other related factors such as soil texture and density of the subsoil and substratum, flooding or ponding hazards, seasonal high water table, slopes as related to cuts and fills, depth to bedrock and differential settling of moved material. This soil interpretation does not take into consideration the use of on-site sewage disposal systems.

Lawns and Landscaping are influenced by soil properties such as texture, depth to seasonal high water table, flooding hazard, depth to bedrock, stoniness, salinity or alkalinity of the surface 12 inches.

Parking Areas are affected by properties such as depth to seasonal high water table, flooding hazard, load-bearing capacity, frost action potential, stoniness, depth to bedrock and topography.

Camp Areas for recreation are subject to heavy foot and some vehicular traffic during the camping season. Soil properties and related factors of importance are depth to seasonal high water table, flooding or ponding hazards, permeability, slope, soil texture, stoniness, and degree of rockiness.

Picnic Areas for recreation are subject to heavy foot traffic. It is assumed that most vehicular traffic will be confined to access roads. Soil properties and other related factors of importance are depth to seasonal high water table, flooding hazard, slope, soil texture,

stoniness and degree of rockiness.

Playgrounds for recreation are subject to heavy foot traffic.

Soil properties and other related factors of importance are soil texture, depth to seasonal high water table, flooding or ponding hazards, depth to bedrock, stoniness and topography.

Septic Tank Filter Fields are influenced by the ease of movement of effluent through the soil. Related factors are seasonal high water table, flooding hazard, slope, depth to bedrock, hydraulic conductivity and ground water contamination hazard.

Sewage Lagoons are rated on the adequacy of the soil material to prevent water seepage from the lagoon. Soil characteristics affecting sewage lagoons are hydraulic conductivity, slope, depth to bedrock, coarse fragments, stoniness, soil texture and organic matter.

Sanitary Land Fills are designed to operate without contaminating water supplies or causing health hazards. Important soil related factors are texture, seasonal high water table, depth to bedrock and topography.

Cemeteries are affected by soil properties and other related factors such as seasonal high water table, flooding hazard, depth to hard rock, slope, stoniness and soil texture.

Pond Reservoir Area is rated on the adequacy of the soil material to prevent water seepage from the reservoir. Soil properties most important are hydraulic conductivity and seepage rate, depth to water

table, and organic matter content.

Fill Material Other than Embankment is rated on the basis that the material is removed and transported to another location to be used as fill material. Important factors are texture, stoniness, soil depth, seasonal high water table, frost action potential, salinity and alkalinity.

Pond Embankment Materials are those features of disturbed soils that affect their suitability for constructing earth fills. These include compaction characteristics, compacted permeability, susceptibility to piping, salinity and alkalinity and organic matter content.

Topsoil is rated on soil properties such as texture, thickness of the surface layer, presence of coarse fragments, organic matter content, wetness of the surface layer, salinity and alkalinity.

Limiting Soil Properties and Hazards

Indicated by Number in Table 1

1. Frequency of flooding or surface ponding
2. Seasonal ground water table within 3 feet
3. Slope percentage:
 - a. Less than 2
 - b. 2 to 5
 - c. 5 to 9
 - d. Less than 9
 - e. More than 9
 - f. 9 to 15
 - g. More than 15
4. Relief
5. Load bearing capacity
6. Hydraulic conductivity (inches per hour):
 - a. 0.20 to 0.63
 - b. 0.63 to 2.00
 - c. More than 2.00
7. Susceptibility to piping:
 - a. Moderate
 - b. High
8. High organic matter content

9. Frost action potential:
 - a. Moderate
 - b. High
10. Salinity and alkalinity
11. Ground water pollution
12. Coarse fragments (gravel, cobble or stones)
13. Depth to loose sand or sand and gravel
14. Soil texture
15. Depth to bedrock (less than 40 inches)

NOTE: These interpretations are for general planning. On-site investigation is needed for specific design and construction.

Table 1. Estimated Soil Limitations or Suitability for Selected Uses.

Map Symbols and Soil Names*	(As) Amsterdam silt loam; (Av) Amsterdam very fine sandy loam	(Ag) Ashuelot gravelly loam	(Bg) Beaverton gravelly loam; (B1) Beaverton loam; (B1) Beaverton loam, dark colored phase	(Bo) Bozeman silt loam; (Bo) Bozeman silt loam, brown phase	(Bc) Bridger silty clay loam; (Bm) Bridger loam; (Br) Bridger gravelly loam	(Bs) Bridger stony loam
Soil Limitations for:						
Cropping	Slight Moderate 3c Severe 3e	Severe 13	Severe 13	Slight Moderate 3c Severe 3e	Slight Moderate 3c Severe 3e	Severe 12
Road & street location	Severe 5,9b Severe 3g,5,9b	Slight	Slight	Severe 5,9b Severe 3g,5,9b	Moderate 5,8,9a Severe 3g	Moderate 3f Severe 3g
Urban development						
-foundations for low bldgs. with basements	Slight Moderate 3f Severe 3g	Slight	Slight	Slight Moderate 3f Severe 3g	Slight Moderate 3f Severe 3g	Severe 12
-lawns and landscaping	Slight Moderate 3f Severe 3g	Moderate 12,13	Moderate 12,13	Slight Moderate 3f Severe 3g	Slight Moderate 3f Severe 3g	Severe 12
-parking areas	Severe 5,9b Severe 3e,5,9b	Slight Moderate 3b	Slight	Severe 5,9b Severe 3e,5,9b	Moderate 3b&c, 5,8,9a Severe 3e	Moderate 3b&c Severe 3e
Recreation						
-camp areas	Slight Moderate 3c&f Severe 3g	Slight Moderate 3c	Slight	Slight Moderate 3c&f Severe 3g	Slight Moderate 3c&f Severe 3g	Severe 12
-picnic areas	Slight Moderate 3e	Slight	Slight	Slight Moderate 3e	Slight Moderate 3e	Moderate 12 Moderate 3f,12 Severe 3g
-playgrounds	Slight Moderate 3b Severe 3c	Slight Moderate 3b Severe 3c	Slight	Slight Moderate 3b Severe 3c	Slight Moderate 3b Severe 3c	Severe 12
Waste disposal						
-septic tank filter fields	Slight Moderate 3c Severe 3e	Slight [#]	Slight [#]	Slight Moderate 3c Severe 3e	Moderate 6b Severe 3e	Severe 3e,12
-sewage lagoons	Moderate 6b Moderate 3b&c,6b Severe 3e	Severe 6c [#]	Severe 6c [#]	Moderate 6b Moderate 3b&c,6b Severe 3e	Moderate 6b Moderate 3b&c,6b Severe 3e	Severe 12
-sanitary land fills	Moderate 14 Moderate 3f,14 Severe 3g	Slight [#]	Slight [#]	Moderate 14 Moderate 3f,14 Severe 3g	Slight Moderate 3f Severe 3g	Severe 12
Other uses						
-cemeteries	Slight Moderate 3f Severe 3g	Slight	Slight	Slight Moderate 3f Severe 3g	Slight Moderate 3f Severe 3g	Severe 12
-pond reservoir area	Severe 7b	Severe 6c	Severe 6c	Severe 7b	Moderate 6b	Severe 12
Suitability as:						
Source of:						
Fill material other than embankment	Poor 5,9b	Good	Good	Poor 5,9b	Fair to good	Poor 12
Pond embankment material	Poor 7b	Poor 6c,12	Poor 6c,12	Poor 7b	Good	Poor 12
Topsoil	Good	Poor 12	Poor 12	Good	Good	Poor 12

* Names of soils are tentative and subject to change.

[#] The possibility of groundwater pollution should be investigated where polluted water will drain through coarse, clean gravels and cobbles which have little filtering capacity.

NOTE: These interpretations will not eliminate the need for on-site soil investigations for design and construction.

Table 1. (Cont'd)

Map Symbols and Soil Names*	(Gc) Gallatin silty clay loam; (Gs) Gallatin silt loam	(Gs) Gallatin silt loam, swampy phase	(Hf) Havre fine sandy loam; (Hf) Havre fine sandy loam, dark colored phase	(Hr) Huffine gravelly loam; (Hs) Huffine silt loam	(Hs) Huffine silt loam, poorly drained phase	(Hg) Hyrum gravelly loam	(Ma) Manhattan loamy sand; (Mf) Manhattan fine sandy loam; (Mf) Manhattan fine sandy loam, smooth phase; (Mf) Manhattan fine sandy loam, gravelly subsoil phase
Soil Limitations for:							
Cropping	Moderate 1,2	Severe 2	Moderate to Severe 1,11	Slight	Severe 2	Severe 13	Moderate 14
Road & street location	Severe 1,2,9b	Severe 2	Slight to Moderate 1	Moderate 2	Severe 2	Slight	Slight Moderate 3f
Urban development							
-foundations for low bldgs. with basements	Severe 1,2	Severe 2	Moderate to Severe 1,2	Severe 2	Severe 2	Slight	Slight Moderate 3f
-lawns and landscaping	Severe 1,2	Severe 2	Slight to Moderate 1	Slight	Severe 2	Moderate 12,13	Slight Moderate 3f
-parking areas	Severe 1,2,9b	Severe 2	Slight to Moderate 1	Moderate 2 Moderate 2,3b	Severe 2	Slight Moderate 3b&c	Slight Moderate 3b&c Severe 3e
Recreation							
-camp areas	Severe 1,2	Severe 2	Slight to Severe 1	Slight	Severe 2	Slight to Moderate 3c	Slight Moderate 3c&f Moderate 3c
-picnic areas	Moderate 1	Severe 2	Slight to Moderate 1	Slight	Severe 2	Slight	Slight Moderate 3f
-playgrounds	Severe 1	Severe 2	Slight to Moderate 1	Slight Moderate 3b	Severe 2	Slight Moderate 3b Severe 3c	Slight Moderate 3b Severe 3c
Waste disposal							
-septic tank	Severe 1,2,11	Severe 2,11	Moderate to Severe 1,2,11	Severe 2,11	Severe 2,11	Slight [#] Moderate 3c	Slight Moderate 3c Severe 3e
-sewage lagoons	Severe 6c,8,11	Severe 2,11	Severe 6c,11	Moderate 6b,11 Severe 6c,11	Severe 2,11	Severe 6c, 11	Severe 6c Severe 3e,6c
-sanitary land fills	Severe 1,2,11	Severe 2,11	Moderate to Severe 1,2	Severe 2,11	Severe 2,11	Slight [#]	Slight Moderate 3f
Other uses							
-cemeteries	Severe 1,2	Severe 2	Moderate to Severe 1,2	Severe 2	Severe 2	Slight	Slight Moderate 3f
-pond reservoir area	Severe 6c	Severe 6c	Severe 6c	Severe 6c	Severe 6c	Severe 6c	Severe 6c
Suitability as Source of:							
Fill material other than embankment	Poor 8,9b	Poor 2	Good	Poor 8,9b	Poor 2	Good	Good
Pond embankment material	Poor 1,7b,8	Poor 2	Poor 6c	Poor 7b,8,9b	Poor 2	Poor 6c,12	Poor 6c
Topsoil	Good	Poor 2	Good	Good	Poor 2	Poor 12	Good

* Names of soils are tentative and subject to change.

The possibility of ground water pollution should be investigated where polluted water will drain through coarse, clean gravels and cobbles which have little filtering capacity.

NOTE: These interpretations will not eliminate the need for on-site soil investigations for design and construction.

Table 1. (Cont'd)

Map Symbol and Soil Names*	(Mv) Manhattan very fine sandy loam; (Mv) Manhattan very fine sandy loam, colluvial phase	(Mg) Manhattan gravelly loam	(Mv) Manhattan very fine sandy loam, shallow phase	(Ms) Millville silt loam	(Ml) Minatare silt loam	(Ml) Minatare silt loam, brown phase	(Rb) Rough broken and mountainous land; (Rw) Riverwash
Soil Limitations for:							
Cropping	Slight Moderate 3c Severe 3e	Moderate 12,14	Severe 15	Slight	Severe 2,10	Moderate 2,10	
Road & street location	Severe 5,9b	Slight Moderate 3f	Moderate to Severe 15	Severe 5,9b	Moderate to Severe 2,9b	Moderate 2,9a	
Urban development							
-foundations for low bldgs. with basements	Slight Moderate 3f	Slight Moderate 3f	Severe 15	Slight	Severe 2	Severe 2	
-lawns and landscaping	Slight Moderate 3f	Slight Moderate 3f	Moderate to Severe 15	Slight	Severe 10	Moderate 10	
-parking areas	Severe 5,9b Severe 3d,5,9b	Slight Moderate 3b&c Severe 3e	Moderate to Severe 3e,15	Severe 5,9b	Moderate to Severe 2,9b	Moderate 2,9a	Too
Recreation							Variable
-camp areas	Slight Moderate 3c&f	Slight Moderate 3c	Slight Moderate 3c	Slight Moderate 3c	Moderate to Severe 2	Slight to Moderate 2	To
-picnic areas	Slight Moderate 3f	Slight Moderate 3f	Slight Moderate 3f	Slight	Slight	Slight	Evaluate
-playgrounds	Slight Moderate 3b Severe 3c	Slight Moderate 3b Severe 3c	Moderate to Severe 3c,15	Slight Moderate 3b Severe 3c	Moderate to Severe 2	Slight to Moderate 2	
Waste disposal							
-septic tank	Slight Moderate 3c Severe 3e	Slight Moderate 3c Severe 3e	Severe 3e,15	Slight [#] Moderate 3c [#]	Severe 2,11	Severe 2,11	
-sewage lagoons	Moderate 5b Moderate 3b&c,6b Severe 3e	Severe 5c Severe 3e,6c	Severe 15	Severe 6c,11 Slight	Moderate 6b, 11	Moderate 6b,11	
-sanitary land fills	Moderate 14 Moderate 3f,14	Slight Moderate 3e	Severe 15		Severe 2,11	Severe 2,11	
Other uses							
-cemeteries	Slight Moderate 3f	Slight Moderate 3f	Severe 15	Slight	Severe 2	Severe 2	
-pond reservoir area	Severe 7b	Severe 6c	Severe 15	Severe 6c	Moderate 6b	Moderate 6b	
Suitability as Source of:							
Fill material other than embankment	Poor 5,9b	Good	Poor 5,9b	Poor 8,9b	Poor 9b	Poor 9b	
Pond embankment material	Poor 7b	Poor 6c	Severe 6c	Poor 7b	Severe 2,7b	Severe 2,7b	
Topsoil	Good	Fair 12,14	Good	Good	Poor 10	Moderate 10	

* Names of soils are tentative and subject to change.

The possibility of ground water pollution should be investigated where polluted water will drain through coarse, clean gravels and cobbles which have little filtering capacity.

NOTE: These interpretations will not eliminate the need for on-site soil investigations for design and construction.

DESCRIPTION OF GALLATIN VALLEY SOILS

Amsterdam Series

The Amsterdam soils are most extensive south of the community of Amsterdam, extending from Camp Creek to the Gallatin River and on the Bridger Range slopes east of Dry Creek. These soils comprise about 11 per cent of the survey area. They developed in calcareous silty materials on upland fans and terraces. Elevation ranges from 4000 to 5000 feet. Mean annual precipitation is 14 to 17 inches. These are well-drained, dark colored soils. They have a thin silt loam surface layer and a thick silt loam or silty clay loam subsoil. The subsoil is underlain by calcareous silt loam to depths of at least 60 inches.

(As) Amsterdam silt loam. This soil is on upland fans and terraces with slopes of 0 to 15 per cent. The dark colored silt loam surface layer is about 6 inches thick. The silt loam or silty clay loam subsoil is 6 to 14 inches thick. Depth to calcareous material varies from 12 to 20 inches.

This soil is used mainly for small grain and hay.

(Av) Amsterdam very fine sandy loam. This soil is on upland fans and terraces with slopes of 0 to 10 per cent. The dark colored very fine sandy loam surface layer is about 4 inches thick. The very fine sandy loam subsoil is 5 to 10 inches thick. Depth to calcareous material varies from 9 to 14 inches.

This soil is used mainly for small grain and hay.

Ashuelot Series

The Ashuelot soils are most extensive south of Three Forks and west of the Madison River and comprise about 2 per cent of the area mapped. They developed in calcareous loamy material on upland benches. Elevation ranges from 4000 to 5000 feet. Mean annual precipitation is 11 to 14 inches. These are well-drained, dark colored soils. They have a thin gravelly loam surface layer and a thick calcareous gravelly and cobbly loam subsoil. The subsoil is underlain by discontinuous layers of cemented fine sand and gravel and extremely thick lime encrustations on coarse fragments at depths between 15 and 20 inches.

(Ag) Ashuelot gravelly loam. This soil is on upland benches with slopes of 2 to 15 per cent. The dark colored gravelly loam surface layer is about 6 inches thick. The gravelly and cobbly fine sandy loam subsoil is 9 to 14 inches thick. Depth to the discontinuous cemented sand and gravel is 15 to 20 inches.

This soil is used mainly for grazing and wildlife.

Beaverton Series

The Beaverton soils are most extensive in an area surrounding the town of Belgrade and in areas bordering Middle Creek, Gallatin River and Cottonwood Creek east of Gallatin Gateway. These soils

comprise about 7 per cent of the area. They developed in calcareous loamy materials on low terraces. Elevation ranges from 4000 to 5000 feet. Mean annual precipitation is 13 to 17 inches. These are well-drained, dark colored soils. They have a thin to moderately thick loam or gravelly loam surface layer and a moderately thick clay loam subsoil. The subsoil is underlain by loose sand and gravel at depths between 10 and 25 inches.

(Bg) Beaverton gravelly loam. This soil is on low terraces with slopes of 0 to 3 per cent. The dark colored gravelly to very gravelly loam surface layer is about 6 inches thick. The very gravelly loam subsoil is 4 to 9 inches thick. Depth to loose sand and gravel varies from 10 to 15 inches.

This soil is used mainly for pasture and wildlife.

(Bl) Beaverton loam. This soil is on low terraces with slopes of 0 to 3 per cent. The dark colored loam surface layer is about 8 inches thick. The clay loam subsoil is 7 to 12 inches thick. Depth to calcareous material varies from 15 to 20 inches. Scattered gravels occur in this unit and gravelly types less than 2 acres in size are included.

This soil is used mainly for small grain, hay, pasture and wildlife.

(BT) Beaverton loam, dark colored phase. This soil is on low terraces with slopes of 0 to 3 per cent. It is similar to the typical

Beaverton loam except the surface layer and subsoil are 1 to 2 inches thicker and are darker in color. The calcareous sand and gravel are at depths between 20 and 24 inches.

This soil is used mainly for small grain, hay, pasture and wildlife.

Bozeman Series

The Bozeman soils are most extensive in the vicinity of Bozeman and the southeastern part of the valley. These soils comprise about 5 per cent of the area. They developed in calcareous silt loam materials on upland fans and terraces. Elevation ranges from 4500 to 6000 feet. Mean annual precipitation is 16 to 24 inches. These are well-drained, dark colored soils. They have a moderately thick silt loam surface layer and a thick silty clay loam subsoil. The subsoil is underlain by calcareous silt loam to a depth of 60 inches.

(Bo) Bozeman silt loam. This soil is on upland fans and terraces with slopes of 2 to 15 per cent. The dark colored silt loam surface layer is about 8 inches thick. The silty clay loam subsoil is 10 to 22 inches thick. Depth to calcareous material ranges from 18 to 30 inches. Included with this soil are small areas less than 2 acres in size of Bridger soils. They occur where the Bozeman and Bridger soils have a common boundary. They make up from 5 to 10 per cent of the unit.

This soil is used mainly for small grain, hay and wildlife.

(Bo) Bozeman silt loam, brown phase. This soil is on upland fans and terraces with slopes of 2 to 15 per cent. It is similar to the typical Bozeman silt loam except the subsoil is silt loam and the substratum is very fine sandy loam. This soil is lighter in color than the typical Bozeman silt loam. Included with this soil are small areas less than 2 acres in size of Amsterdam soils. They occur where the Bozeman and Amsterdam soils have a common boundary. They make up from 5 to 10 per cent of the unit.

This soil is used mainly for small grain, hay and wildlife.

Bridger Series

The Bridger soils are most extensive on the foothills and alluvial fans of the Bridger, Gallatin and Madison ranges. These soils comprise about 10 per cent of the area. They developed in loam or clay loam materials on upland fans and terraces. Elevation ranges from 4500 to 6000 feet. Mean annual precipitation is 18 to 24 inches. These are well-drained, dark colored soils. They have a moderately thick loam surface and a thick clayey subsoil. The subsoil is underlain by calcareous, stony and gravelly loam to a depth of 60 inches. Gravel, cobble and stone comprise 5 to 30 per cent of the volume throughout the soil profile.

(Bm) Bridger loam. The soil is on alluvial fans and foot slopes with slopes of 2 to 30 per cent. The dark colored loam surface layer

is about 8 inches thick. The clayey subsoil is 16 to 24 inches thick. Depth to calcareous material varies from 24 to 32 inches. The subsoil is underlain by stony and gravelly loam.

This soil is used mainly for small grain, hay, grazing and wild-life.

(Bc) Bridger silty clay loam. This soil is on alluvial fans and foot slopes with slopes of 2 to 30 per cent. The dark colored silty clay loam surface layer is about 8 inches thick. The silty clay subsoil is 16 to 24 inches thick. Depth to calcareous material varies from 24 to 32 inches. The subsoil is underlain by stony and gravelly loam.

This soil is used mainly for small grain, hay, grazing and wild-life.

(Br) Bridger gravelly loam. This soil is on alluvial fans and foot slopes with slopes of 2 to 30 per cent. It is similar to the Bridger loam except for the increased gravel content in the soil. The nitrogen, phosphorus and calcium content is generally less than that of the Bridger loam.

This soil is used mainly for small grain, grazing and wildlife.

(Bs) Bridger stony loam. This soil is on alluvial fans and foot slopes with slopes of 0 to 20 per cent. The dark colored stony loam surface layer is about 8 inches thick. The stony, gravelly and cobbly sandy clay loam subsoil is 16 to 24 inches thick. Depth to calcareous

material ranges from 24 to 32 inches.

This soil is used mainly for grazing and wildlife.

Gallatin Series

The Gallatin soils are most extensive in areas bordering the Gallatin and East Gallatin rivers and Reese, Bridger and Bozeman creeks. These soils comprise about 7 per cent of the area. They developed in calcareous silt loam materials on low stream terraces. Elevation ranges from 4500 to 6000 feet. Mean annual precipitation is 14 to 20 inches. These are somewhat poorly to poorly drained, dark colored soils. They have a moderately thick silt loam surface layer and a thick silt loam or clayey subsoil. The subsoil is underlain by loose sand and gravel at depths between 30 and 60 inches.

(Gc) Gallatin silty clay loam. This soil is on low stream terraces with slopes of 0 to 2 per cent. It is similar to the typical Gallatin silt loam except the surface layer has a silty clay loam texture and the subsoil has a silty clay texture.

This soil is used mainly for small grain, hay, pasture and wildlife.

(Gs) Gallatin silt loam. This soil is on low stream terraces with slopes of 0 to 2 per cent. The dark colored silt loam surface layer is about 8 inches thick. The silty clay loam subsoil is 22 to 32 inches thick. Depth to loose sand and gravels is 30 to 40 inches.

This soil is used mainly for small grain, hay, pasture and wildlife.

(Gs) Gallatin silt loam, swampy phase. This soil is on low stream terraces with slopes of 0 to 2 per cent. It is similar to the typical Gallatin silt loam except this soil has a permanent swampy condition because of seepage or a high water table. Some of this soil has been drained in past years to allow for production of small grains and hay.

This soil is used mainly for grazing and wildlife.

Havre Series

The Havre soils are most extensive in better drained areas on low terraces. These soils comprise about 4 per cent of the area. They developed in calcareous sandy materials of recent origin. Elevation ranges from 4000 to 5000 feet. Mean annual precipitation is 10 to 18 inches. These are light to dark colored, moderately well-drained soil. They have a moderately thick fine sandy loam to loam surface layer and a thick fine sandy loam to silty clay loam subsoil. The subsoil is underlain by loose sand and gravel at depths between 30 and 60 inches.

(Hf) Havre fine sandy loam. This soil is on low stream terraces with slopes of 0 to 2 per cent. The dark colored fine sandy loam to loam surface layer is about 8 inches thick. The fine sandy loam subsoil is 22 inches or more in thickness. Scattered gravels occur on the surface in some areas.

This soil is used mainly for small grain, hay, pasture and wildlife.

(Hf) Havre fine sandy loam, dark colored phase. This soil is on low stream terraces with slopes of 0 to 2 per cent. It is similar to the typical Havre fine sandy loam except this soil has a darker color, and in some areas the subsoil consists of a silty clay loam texture.

This soil is used mainly for small grain, hay, pasture and wildlife.

Huffine Series

The Huffine soils are most extensive west and south of Bozeman and comprise about 4 per cent of the area. They developed in calcareous silty material on alluvial fans. Elevation ranges from 4500 to 6000 feet. Mean annual precipitation is 16 to 24 inches. These are somewhat poorly to poorly drained dark colored soils. They have a moderately thick gravelly loam or silt loam surface layer and a clay loam subsoil which is calcareous in the lower portion. The subsoil is underlain by loose sand and gravel at depths between 20 and 40 inches.

(H1) Huffine gravelly loam. This soil is on alluvial fans with slopes of 0 to 5 per cent. The dark colored gravelly loam surface layer is about 8 inches thick. The gravelly clay loam subsoil is 7 to 12 inches thick. Depth to calcareous material varies from 15 to 20 inches.

This soil is used mainly for small grain, hay, pasture and wildlife.

(Hs) Huffine silt loam. This soil is on broad fan terraces with slopes of 0 to 5 per cent. The dark colored silt loam surface layer is about 8 inches thick. The silty clay loam subsoil is 8 to 14 inches thick. Depth to calcareous material varies from 16 to 22 inches.

The main uses for this soil are small grain, hay, pasture and wildlife.

(Hs) Huffine silt loam, poorly drained phase. This soil is in shallow sloughs, depressions or drainageways with slopes of 0 to 2 per cent. It is similar to the typical Huffine silt loam except the surface soil in most places is darker and in many places it is shallower and more gravelly.

The main uses for this soil are grazing and wildlife.

Hyrum Series

The Hyrum soils are most extensive in the vicinity of the Ross Creek drainage and comprise about 1 per cent of the area. They developed in calcareous loamy materials on alluvial fans. Elevation ranges from 4500 to 5500 feet. Mean annual precipitation is 16 to 19 inches. These are well-drained, dark colored soils. They have a moderately thick gravelly loam surface layer and a moderately thick gravelly loam to gravelly clay loam subsoil. The subsoil is underlain by

calcareous gravelly loamy sand or sand at depths between 15 and 30 inches.

(Hg) Hyrum gravelly loam. This soil is on upland alluvial fans with slopes of 0 to 10 per cent. The dark colored gravelly loam surface layer is about 7 inches thick. The weekly calcareous gravelly loam to gravelly clay loam subsoil is 10 to 17 inches thick. Depth to loose sand and gravel varies from 18 to 25 inches.

The main uses for this soil are small grain, hay and wildlife.

Manhattan Series

The Manhattan soils are most extensive in the vicinity of Manhattan, west of Dry Creek, west of Camp Creek and south of the communities of Three Forks and Willow Creek. These soils comprise about 16 per cent of the area. They developed in calcareous sandy alluvium on upland fans and terraces. Elevation ranges from 4000 to 5000 feet. Mean annual precipitation is 10 to 15 inches. These are well-drained, light to dark colored soils. They have a thin to moderately thick sandy loam surface layer and a thick fine sandy or loamy fine sand subsoil. The subsoil is underlain by calcareous, stratified materials at depths between 15 and 60 inches.

(Ma) Manhattan loamy sand. This soil is on upland fans and terraces with slopes of 0 to 15 per cent. The light colored loamy sand surface layer is about 8 inches thick. The calcareous loamy sand and

and fine sand subsoil is 12 to 17 inches thick. Stratified layers of gravel and sand occur at a depth ranging from 20 to 25 inches.

The main uses for this soil are grazing and wildlife.

(Mf) Manhattan fine sandy loam. This soil is on upland fans and terraces with slopes of 0 to 15 per cent. The light colored fine sandy loam surface layer is about 8 inches thick. The calcareous fine sand subsoil ranges in thickness from 30 to 40 inches over a coarse variable substrata.

The main uses for this soil are grazing, wildlife and limited cropping.

(Mf) Manhattan fine sandy loam, gravelly subsoil phase. This soil is on foot slopes with slopes of 2 to 15 per cent. It is similar to the typical Manhattan fine sandy loam except for the increased gravel content in the subsoil.

The main uses for this soil are grazing, wildlife and limited cropping.

(Mf) Manhattan fine sandy loam, smooth phase. This soil is on alluvial fans with slopes of 0 to 5 per cent. The light colored fine sandy loam surface layer is about 8 inches thick. The fine sandy loam subsoil is 7 to 10 inches thick. Depth to calcareous very fine sandy loam is 15 to 18 inches. Stratified layers of fine sand and gravel occurs at depths between 24 and 36 inches.

The main uses for this soil are small grain, hay, pasture and wildlife.

(Mg) Manhattan gravelly loam. This soil is on upland fans and terraces with slopes of 0 to 15 per cent. The light colored gravelly loam surface layer is about 8 inches thick. The calcareous gravelly loam surface layer is about 8 inches thick. The calcareous gravelly loam subsoil ranges in thickness from 10 to 18 inches. Depth to stratified layers of sand and gravel is between 16 to 26 inches.

The main uses for this soil are small grain, hay, pasture and wildlife.

(Mv) Manhattan very fine sandy loam. This soil is on upland fans and terraces with slopes of 0 to 15 per cent. The light colored very fine sandy loam surface layer is about 8 inches thick. The calcareous very fine sandy loam subsoil ranges in thickness from 10 to 18 inches over stratified layers of loamy sand and sandy loam to a depth of 60 inches. A few gravels occur throughout the soil profile.

The main uses for this soil are small grain, hay, pasture and wildlife.

(Mv) Manhattan very fine sandy loam, colluvial phase. This soil is on upland fans and terraces with slopes of 0 to 15 per cent. It is similar to the typical Manhattan very fine sandy loam except the soil color is darker.

The main uses for this soil are small grain, hay and pasture.

(Mv) Manhattan very fine sandy loam, shallow phase. This soil is on upland fans and terraces with slopes of 0 to 15 per cent. It is similar to the typical Manhattan very fine sandy loam except the subsoil is underlain by calcareous sandstone at depths between 15 and 25 inches.

The main uses for this soil are grazing and wildlife.

Millville Series

The Millville soils are most extensive in the vicinity of Springhill and comprise about 1 per cent of the area. They developed in calcareous silty materials on alluvial fans. Elevation ranges from 4000 to 5500 feet. Mean annual precipitation is 16 to 19 inches. These are well-drained, dark colored soils. They have a moderately thick silt loam surface layer and a thick silt loam subsoil which is calcareous in the lower part. The subsoil is underlain by loose sand and gravel at depths between 25 and 40 inches.

(Ms) Millville silt loam. This soil is on upland alluvial fans with slopes of 0 to 10 per cent. The dark colored silt loam surface layer is about 7 inches thick. The silt loam subsoil is 13 to 19 inches thick. Depth to calcareous material varies from 20 to 26 inches. Well-rounded gravel is scattered throughout the subsoil.

The main uses for this soil are small grain, hay and wildlife.

Minatare Series

The Minatare soils are most extensive north of Central Park and in the Madison River Valley. They comprise about 2 per cent of the area. They developed in loamy alluvium on bottomlands and low terraces along streams. Elevation ranges from 4000 to 5000 feet. Mean annual precipitation is 10 to 15 inches. These are somewhat poorly to poorly drained, light colored soils. They have a thin silt loam surface layer and a thick silt loam to silty clay subsoil. The subsoil is underlain by stratified silt loam, loam and sandy loam at depths between 30 and 60 inches. These are strongly saline soils from the surface downward.

(M1) Minatare silt loam. This soil is on alluvial bottomlands with slopes of 0 to 2 per cent. The light colored silt loam surface layer is about 8 inches thick. The silt loam or silty clay subsoil is 22 to 32 inches thick. Depth to the stratified substratum ranges between 30 and 40 inches.

The main uses for this soil are grazing, hay and wildlife.

(M1) Minatare silt loam, brown phase. This soil is on alluvial bottomlands with slopes of 0 to 2 per cent. It is similar to the typical Minatare silt loam except this soil has less salt accumulation because of better drainage and a lower ground water table.

The main uses for this soil are small grain, hay and pasture.

MISCELLANEOUS LAND TYPES

(Rb) Rough broken and mountainous land. This miscellaneous land type is distributed throughout the area. It comprises about 25 per cent of the area. The rough broken land is dominately steep and stony. It is broken by numerous intermittent drainage channels. The soils range from shallow to deep. The mountainous land occurs mainly on the southern and eastern boundaries of the area. This land is mostly steep, rocky and timbered.

The main uses for this land type is grazing and wildlife.

(Rw) Riverwash. This miscellaneous land type comprises about 8 per cent of the area. It includes a wide variety of recently deposited sediments that occur in narrow strips or bars on low levels near streams. It also includes small islands in major stream channels as well as intermittent stream beds subject to periodic overflow during high water. These sediments are generally very gravelly and cobbly and include mostly sandy textures. However, some finer textured sediments are included.

The main uses for this land type are limited grazing and wildlife.

Table 12. Presentations of Soil Interpretations and Overlay Maps.

Month	Place	Audience	Attendance
April	MSU	Architecture Class	20
November	MSU	Real Estate Class (Commerce)	45
December	Bozeman	County Commissioners	3
March	MSU	Soil Survey & Classification Class	30
November	Bozeman	City County Planning Board	25
May	MSU	Earth Sciences Lecture Series	30
February	MSU	Economics Class in Land Use	14
May	Bozeman	Citizens Advisory Council	10
May	Bozeman	Citizens Advisory Council	10
June	MSU	Soil Morphology Class	4
Aug 70- Aug 71	MSU	Individual Students (architecture, engineering, recreation area management, range management)	22
Aug 70- Aug 71	MSU	Other Individuals (most were interested in real estate development)	9
August	Manhattan, Kansas	American Society of Horticultural Science	30
June	Laramie, Wyoming	Soil Science Society of America, Western Division	130
June	San Fran., Calif.	Western Regional Committee on Alternative Uses of Land and Appraisal of Soil Resources	12

Month	Place	Audience	Attendance
Summer- Autumn, '71	Red Lodge	Beartooth RC&D Annual Meeting	200
	Bozeman	Soil Conservation Service Training Meetings	60
	Missoula	Soil Conservation Service Training Meetings	40
	Lewistown	Soil Conservation Service Training	40
	Billings	Soil Conservation Service Training Meetings	35
February	Manhattan, Kansas	Citizens Conference on Taxes	80
March	Chicago	Interregional Resource Economics Committee	10
October	Bozeman	President, Gallatin Canyon Planning Association	1
October	Calgary	Division of Agr. Inst. of Canada	35
October	Bozeman	Western Regional Land Judging Participants	30
* Including New Soil Map of Gallatin Canyon			
November	Ophir School	Gallatin Canyon Planning Assoc.	15
November	Bozeman	Plant & Soil Science Seminar	30
November	Bozeman	MSU Gallatin Canyon Study Group	30
December	Bozeman	Gallatin County Realtors Assoc.	30
1972--			
January 12	Bozeman	Soils 201 Introductory Soils Students	80
January 26	Calgary	Planning Div.-Canadian Nat'l Parks Service	20

Month	Place	Audience	Attendance
January 27	Calgary	Private Consulting Co., Calgary	3
January 27	Calgary	Faculty of Environmental Design, University of Calgary	8
February	Bozeman	Communication with Gal. Canyon Resident	1
February 26	Bridger Canyon	Earth Sciences Club, M.S.U.	25
March 10	MSU	Discussion with Rep. for Land Development Corp.	2
March 16	Big Sky	Professional Planners of Montana	25
March 20	Helena	State Resource Officials	5
March 23	Bozeman	NSF Planning Consultants and Executive Committee	20
Mid-March	MSU	State Legislator, Extension Specialist	2
April 3	Forsyth	Rosebud Co. Commissioners and Planning Board	25
April 4	Bozeman	High School Students	100
April 20	MSU	Architecture Class	40
May 22	MSU	Plant & Soil Science Department	24
June 1	MSU	State Extension Personnel	40
June 1	MSU	Soil Classification and Conservation Class	65

MICHELSON SERIES

The Michelson series is a member of the fine-loamy, mixed family of Argic Cryoborolls. Typically, Michelson soils have a dark grayish brown, loam A1 horizon, a brown, clay loam B2t horizon; and a prominent, very pale brown Cca horizon of loam and clay loam.

Representative Profile: Michelson loam - native grass. Colors are for dry soil unless otherwise stated.

- A1 - 0- 6" Dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; weak medium blocks parting to moderate fine crumb structure; slightly hard, very friable, slightly sticky and slightly plastic; non calcareous; clear smooth boundary.
- B2t - 6-11" Brown (10YR 4/3) smooth clay loam, very dark brown (10YR 3/2) moist; moderate medium and fine blocky structure; hard, firm, sticky and plastic; continuous clay films coating peds; non calcareous; clear smooth boundary.
- B22t - 11-20" Brown (10YR 5/3) clay loam, brown (10YR 4/3) moist; strong medium and fine blocky structure with continuous clay coatings on peds; hard, firm, sticky and very plastic; non calcareous; abrupt smooth boundary.
- Clca - 20-32" Very pale brown (10YR 7/3) loam, brown (10YR 5/3) moist; weak coarse blocky structure; slightly hard,

very friable, slightly sticky and slightly plastic;
violently calcareous with common fine threads of
segregated lime, diffuse smooth boundary.

C2ca - 32-60" Light yellowish brown (10YR 6/4) stratified loams
and clay loams, yellowish brown (10YR 5/4) moist;
massive structure; hard, friable, sticky and plastic;
strongly calcareous with few coarse threads of lime.

Type Location: Gallatin County, Montana. 1,079' West, 1,155'
South of the NE corner of section 17, T. 7 S., R. 4 E., on a 4% east
facing slope - west of the Ophir school.

Range in Characteristics: Solum thickness ranges from 18 to 30
inches. Content of coarse fragments range from a few pebbles in some
pedons to 30% in the 10 to 40 inch portion of the profile. Below 40
inches cobbles and gravel range up to 80% in some pedons. Michelson
soils are usually moist more than half the time when not frozen and
are never dry for 60 consecutive days between 4 and 12 inches when the
soil temperature is above 41⁰ F. The mean annual soil temperature is
between 40 and 44⁰ F and the mean summer soil temperature is between
53 and 57⁰ F. The mollic epipedon ranges from 8 to 20 inches thick
and usually includes the upper part of the B2t horizon. Color of the
A1 horizon is in hue of 10YR or 7.5YR, value of 2 or 3, and 3 or 4 dry,
and chroma of 2 or 3 moist or dry. The B2t horizon has colors in hue
of 10YR or 7.5 YR, value of 3 or 4 moist and 4 or 5 dry, and chroma

of 2, 3 or 4 moist or dry. It is clay loam averaging between 30 and 36 percent clay. Structure is moderate medium prismatic and blocky or strong medium or fine blocky and is friable or firm. The Cca horizon has hue of 2.5Y or 10YR, value of 5 or 6 and 6 or 7 dry, and chroma of 3 or 4. It is loam or clay loam.

Competing Series and Their Differentiae: These are the Adel, Leavitt, and Teton series in the same family and the Bridger and Hobacker in different families. Adel, Teton and Hobacker soils lack argillic horizons. Bridger soils are in the fine family and Leavitt soils are developed in glacial till. Hobacker soils have over 35% coarse fragments in the family control section.

Setting: Michelson soils are on old nearly level to gently sloping terraces and side slopes at elevations between 6,200 and 6,700 feet. Mean annual precipitation is 20 to 30 inches, 11 to 20 inches of this comes in the form of snow. The mean annual air temperature ranges from 35 to 40⁰ F and the average summer temperature is from 52 to 56⁰ F. Frost usually occurs at least once during each of the summer months.

Principal Associated Soils: These are the Hobacker, Adel, Bigel, Bearmouth and Leavitt. Bigel and Bearmouth soils have sand and gravel at depths less than 20 and 40 inches respectively.

Drainage and Permeability: Well drained with moderate permeability and slow to moderate runoff.

Use and Vegetation: Used primarily for range. Native vegetation is Idaho fescue, bluebunch wheatgrass, Big sage and other shrubs and forbs.

Distribution and Extent: Inextensive in the survey area. The largest area of these soils is between the mouth of West Fork and Beaver Creeks on a high terrace.

LOBERG SERIES

The Loberg series is a member of the clayey-skeletal mixed family of Typic Cryoboralfs. Typically, Loberg soils, under a layer of organic duff, have a gray loam A2 horizon, a mixed A2 and B2 horizon of sandy clay loam, a thick B2t horizon of heavy clay loam that has over 35% cobble and stone.

Representative Profile: Loberg stony loam - forested. Colors are for dry soil unless otherwise noted.

- 01 - 3-0" Organic duff consisting of pine needles, twigs, and other forest litter.
- A2 - 0-24" Gray (10YR 5/1) loam, dark grayish brown (10YR 3/2) moist; weak medium platy structure breaking to weak medium blocks; slightly hard, very friable, slightly sticky and slightly plastic; non calcareous; abundant clear quartz grains on faces of peds; clear smooth boundary.
- A & B - 24-36" (A) light brown (7.5YR 6/3) sandy clay loam, dark brown (7.5YR 4/3) moist; (B) lamella and bands of dark brown (7.5YR 4/3) and (7.5YR 3/3) moist; weak coarse blocky structure; hard, friable, sticky and plastic; non calcareous; clear smooth boundary.
- B2t - 36-72" Dark brown (7.5YR 4/4) sandy clay loam, weak coarse blocky structure; hard firm, sticky and plastic; non

calcareous; abrupt wavy boundary.

- C - 72-84" Brown (10YR 5/3) sandy loam, dark brown (10YR 3/3)
moist; massive structure; slightly hard, very friable,
non sticky and slightly plastic, strongly calcareous.

Type Location: Gallatin County, Montana. 1,815' East, 330' South
of the NW corner of Section 29, T. 6 S., R. 3 E., on a 30% slope, north
aspect.

Range in Characteristics: Loberg soils are usually moist. They
have mean annual soil temperatures that range from 35 - 40° F and an
average summer temperature of 43 - 47° F under an O horizon and under
trees. Solum thickness typically is 50 to 60 inches and ranges from
40 to 80 inches. They are non calcareous to 60 inches or more. Coarse
fraction ranges from 35 to 70% in the 10 to 40 inch part of the profile.
Pedons on concave landscapes commonly have more fragments throughout.
Fragments are dominantly subangular, of gravel, cobble and stone size.
The A2 horizon ranges from 10 to 30 inches thick in hue of 10YR or 7.5
YR, value of 5 or 7 dry and chroma of 1 or 2. The B2t horizon has hue
of 7.5YR or 5YR, value of 4 or 5 dry and chroma of 3 or 4. It has from
35 to 45 percent clay in the fine fraction. The C horizon is sandy
loam to clay loam.

Competing Series and Their Differentiae: These are the Berglo,
Garlet and Rambler series. The Berglo series differs only by having
lime in the profile between 30 and 60 inches. Garlet and Rambler series

are members of the loamy-skeletal family. They have thinner sola and are developed in material weathered from beltrock rather than glacial till.

Setting: The Loberg soils are on hilly to steep glacial till, mountainous landscapes, at elevations ranging from 6,000 to 8,000 feet. The regolith is deep unconsolidated materials deposited by alpine glaciers. The mean annual air temperature ranges from 33 to 37⁰ F and the mean summer temperature ranges from 50 to 55⁰ F. Mean annual precipitation is 25 to 50 inches, 15 to 40 inches of this comes in the form of snow. It is common to have a frost during each of the summer months.

Principal Associated Soils: These are the competing Berglo, Garlet and Rambler soils.

Drainage and Permeability: Well drained. Moderately slow permeability and moderate runoff.

Use and Vegetation: Forest products, grazing and shelter for wildlife. Vegetation consists of Lodgepole pine and Douglas fir with an understory of Elksedge, pine grasses, and shrubs.

Distribution and Extent: Approximately 8,000 acres in the survey area.

KISSICK SERIES

The Kissick series is a member of the fine mixed family of Vertic Cryoborolls. Typically, Kissick soils have a dark gray A1 horizon that extends into the lower horizons as coatings on structure faces. Below 7 inches the wedge shaped peds intersect. These soils have wide cracks to the surface when dry.

Representative Profile: Kissick clay - pasture grass. Colors are for dry soil unless otherwise noted.

- A11 - 0- 4" Dark gray (10YR 4/1) clay, very dark brown (10YR 2/2) moist; weak fine blocky structure; very hard, very firm, very sticky and very plastic; non calcareous; clear smooth boundary.
- A12 - 4-30" Dark gray (2.5Y 4/0) clay, black (10YR 2/1) moist; moderate medium and fine blocky structure; very hard, very firm, very sticky and very plastic; non calcareous; clear smooth boundary.
- A13Ca - 30-40" Gray (10YR 5/1) clay, dark gray (10YR 4/1) moist; massive structure; very hard, very firm, very sticky and very plastic; strongly calcareous with common, fine, prominent nodules and threads of segregated lime; abrupt smooth boundary.
- Cca - 40-60" Gray (2.5Y 5/1) clay, olive gray (5Y 4/2) moist; massive structure; very hard, very firm, very sticky

and very plastic; common fine distinct rust and gray colored mottles, strongly calcareous with common, medium and large, prominent nodules of segregated lime.

Type Location: Gallatin County, Montana. 745' South, 20' West of the E 1/4 corner of section 8, T. 7 S., R. 4 E., about 1 mile South of Bucks T4 ranch on the west side of highway 191.

Range in Characteristics: Kissick soils are usually moist more than half the time when not frozen and are never dry for 60 consecutive days between 4 and 12 inches when the soil temperature is above 41° F. The mean annual soil temperature ranges from 40 - 44° F and the average summer soil temperature is 53 - 57° F. They have cracks to the surface which become intersecting below 7 to 10 inches. Intersecting slickensides are strongest between 7 or 10 and 17 to 20 inches. Some pedons lack a B horizon and tongues of the A horizon extend into the C horizon. Depth to calcareous soil ranges from 15 to 40 inches. Colors of the A horizons are in hue of 10YR or 2.5Y, value of 4 or 5 dry, 1 or 2 moist and chroma of 0, 1 or 2 moist or dry. B horizons are in hue of 10YR or 2.5Y, value of 4 or 6 dry, 3 or 4 moist in chroma of 1, 2 or 3. Colors of C horizons range in hue from 5Y to 10YR, values of 5, 6 or 7 dry in chroma of 1, 2 or 3.

Setting: Kissick soils occupy nearly level to gently sloping stream terraces at elevations of about 6,000 feet. Average annual

precipitation is 20 to 30 inches, 11 to 20 inches of this comes in the form of snow. Mean annual air temperature ranges from 35 - 40⁰ F and the average summer temperature is 52 - 55⁰ F. It is common to have a frost in each of the summer months.

Principal Associated Soils: These include the Bigel and Bearmouth.

Drainage and Permeability: Kissick soils are well drained, runoff is medium, and permeability is slow.

Use and Vegetation: Primary use is pasture.

Distribution and Extent: Inextensive in the Gallatin Canyon Area.

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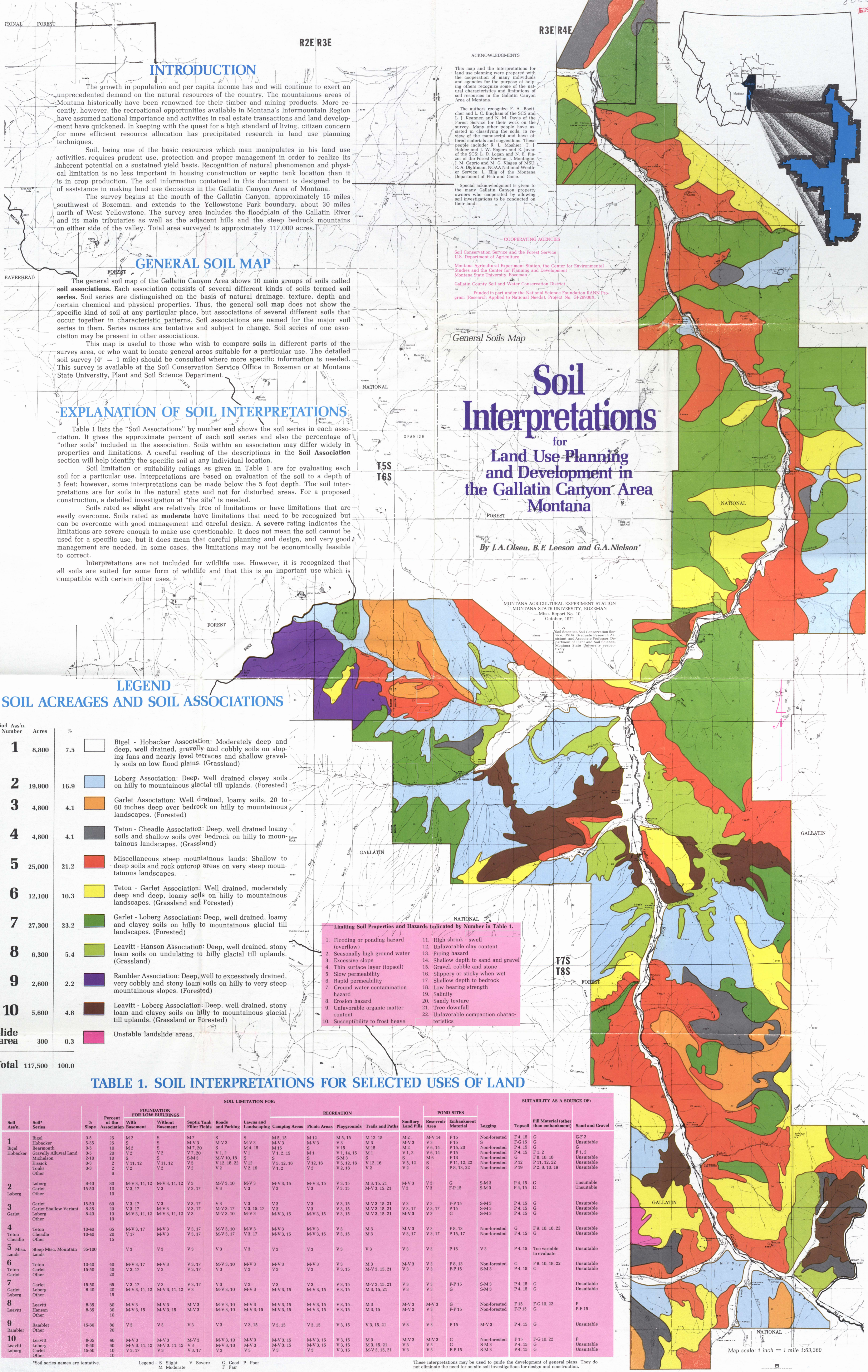
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CLIMATE

Climate of the Gallatin Canyon is influenced to a large degree by very mountainous terrain to the east and west. Elevation in the canyon itself ranges from about 6,800 feet at the northwest corner of Yellowstone Park to near 5,000 feet at the town of Gallatin Gateway 40 miles north. Precipitation has been measured at only a few sites along the river itself, and these records show a rather surprising lack of uniformity in annual amounts from area to area. Annual precipitation at Squaw Creek Ranger Station averages close to 21 inches (more the last few years), while at Gallatin Ranger Station just inside the park boundary the average for several earlier years was 16 inches. In the area where the canyon broadens, from the lower West Fork basin to Buck Creek, fragmentary records indicate annual averages less than 20 inches—perhaps even less than 16 inches in drier locations. Along mountain ridges both east and west it is estimated that totals may run as high as 60 or 70 inches a year.

Temperature records of any length in the canyon proper do not exist, but the area is known for relatively cool summers and cold, but not really extreme winters. The freeze-free season at Gallatin Gateway is estimated at about 95 to 100 days. (It is 108 days on the Montana State University campus in Bozeman.) At the south end of the valley the freeze-free season is less than 50 days and at many locations frost can be expected at least once during all summer months.

TIMBER

Logging started in the Gallatin Canyon in the late 1800's. The major products of this period were lumber and railroad ties. Most of the major drainages and some of the smaller ones were logged. Drainages that were logged for ties in-

clude Logger Creek, Hell Roaring Creek, Creek Creek, Taylor Fork and Buck Creek.

The next major logging activity was in the early 1950's when pulpwood was cut in the West Fork for the Eastern market. The first major sale on National Forest land was in Portal Creek in 1953. The timber was sold as pulpwood but was actually cut into lumber at the mill in Belgrade. Since that time approximately 7 million board feet a year have been cut from National Forest land and about the same amount from private land. In addition, numerous free-use permits are given each year to people who want firewood. There are also many small sales made to ranchers, farmers, and others who cut posts, corral poles, and other products for themselves or for resale.

Timber in the National Forest is managed on a sustained-yield basis. The timber management plan that regulates the cut was written in 1966 and is revised at least every tenth year. The regulated cut has an average rotation age of 125 years for all species. This means that all trees should be cut from a given area by the time they are 125 years old. In selective logging the area would be cut several times in the 125-year rotation. For mature saw timber, the regulated cut in Gallatin Canyon is 930 acres with approximately 11.4 million board feet harvested each year. This cut has been considerably reduced the last few years so that multiple-use studies can be made in several areas in the canyon.

About 75 percent of saw-timber size trees in the canyon are over-mature lodgepole pine. These trees are heavily infected with dwarf mistletoe and cancomra rust. These diseases increase mortality, reduce growth, and reduce the quality of lumber produced. The disease problems leave little choice but to clearcut infected stands. Once a stand is relatively disease free, other methods of cutting may be used.

In the last year there has been a serious outbreak of mountain pine beetle in the

Gallatin Canyon. This beetle attacks the larger trees, usually over 7 inches in diameter, and causes heavy mortality in old stands.

There are heavy accumulations of natural fuels on the ground under old stands. These old stands increase logging slash because some timber cannot be utilized as lumber due to rot and other defects. This fuel is disposed of by controlled burning when logging is completed. This method of slash disposal may not be needed in the next rotation if good management will reduce the natural mortality.

There are numerous old clearcuts in the canyon that need thinning because of overstocking of young lodgepole pine. Approximately 250 acres of the old clearcuts in Squaw Creek and 100 acres in Portal Creek will be thinned each year for the next few years.

Most of the saw logs cut in the canyon go to the large mills at Belgrade, Maudlow, and Livingston. Logs also are used by the mill at Gallatin Gateway and by the pole-treatment plant in Bozeman. Several post and pole mills utilize smaller size trees from the canyon.

Of the 339,933 acres of National Forest land in the Gallatin area, only 149,847 acres are classified as commercial forest land. Most of this will never be logged because other uses such as recreation and wildlife have a higher key value.

GEOLOGY

The Gallatin Canyon Area covered by this report is at the southeastern extremity of the Northern Rocky Mountain Province and includes portions of the Madison and Gallatin mountain ranges. The area joins the northwest corner of Yellowstone National Park in south-western Montana (see attached map). The Gallatin River forms the arbitrary boundary between two mountain ranges: the Madison Range north of Hebgen Lake and west of the river, and

the Gallatin Range east of the river. The two ranges are one geologic unit with no structural demarcation between them. A few peaks exceed elevations of 11,000 feet with many over 10,000 feet.

From Yellowstone Park northward, the Gallatin flows transverse to the geologic structure and cuts through four distinct structural units. It descends from Yellowstone Park first through basically downward warped rocks of Cretaceous age (70 to 130 million years old). These Cretaceous rocks are composed of black shales and soft impure sandstone that are highly erodible and are a major source of sediment carried in streams during periods of heavy rainfall and rapid snowmelt. When these soft rocks are wet, they become quite unstable and are subject to mud flows and landslides. Such slide areas are in evidence along the Taylor Fork drainage. A few lesser structures, such as the Snowflake Springs thrust and the Buck Creek anticline near Almart Lodge, bring up to the surface older formations of limestone or sandstone of late Paleozoic or early Mesozoic age (about 250 million years old). Volcanic breccias form the topmost caps of the Gallatin Mountains. Erosional and depositional processes contribute sediments from the higher areas to the soils of the drainageways.

From Buck Creek to the mouth of the West Fork, the river flows through an area of downwardwarped Cretaceous sandstone, limestone, and shale similar to that of the West Fork drainage. Purplish and green conglomerate, sandstone, and shale beds of the Kootenai formation can be observed from the highway. Dark gray shale and sandstone of the Colorado group are common in the West Fork.

Below the West Fork, the river plunges through the Spanish Peaks block in a deep canyon for roughly 15 miles. The Spanish Peaks block is the dominant geologic unit of the area in terms of uplift and boldness. It is bordered on the south by the West Fork and on the north

by Spanish and Squaw Creeks. The valleys of these three streams owe their existence mostly to weaker, less resistant rocks adjacent to the uplifted block. The Spanish Peaks uplift occurred during the Laramide time (50 to 65 million years ago). Prior to the mountain uplift, this area was covered by softer sandstone, limestone, and shale; but these rocks have been peeled off the top of the uplifted block by erosion. Ancient Pre-Cambrian gneisses and schists are now exposed throughout the uplift. Narrow canyon walls, steep ravines, crystalline limestone and clear tributary waters are common in this terrain. Periodic flood surges fed by Pleistocene glaciers that discharged from nearby alpine peaks have sporadically filled the gorges, but most of the material has been washed away. Only terrace remnants remain as evidence of these episodes.

At Squaw Creek and Spanish Creek, Paleozoic and Mesozoic sedimentary rocks once again descend structurally. These rocks are the same limestones, sandstones and shales which predominate south of the Spanish Peaks block. Except for a small arch between Squaw Creek and the mouth of the Gallatin Canyon where ancient rocks once again cause steep narrow gorges, the river flows through softer rocks and out onto the broad Gallatin Valley floor. This very wide floodplain is the result of this area being downwarped in the latter half of Cenozoic time. Soil materials have been deposited since this time or approximately during the last 35 million years. Deposition continues to the present but at a diminished rate.

Within the basins of the West Fork, Beaver, Porcupine, Moose, Portal, Tepee, and other tributaries to the Gallatin are large areas of glacial till and till-like materials from mass-gravity movement. These materials blanket the downwardwarped geologic formations and form the parent material of Loberg, Leavitt and Hanson soils which comprise approximately 32,000 acres or about 27% of the survey area.

RECREATION

The Gallatin River originates high in northwestern Yellowstone National Park and flows north into Montana between the Gallatin and the Madison Mountain Ranges. The Gallatin Canyon Area contains some of the most rugged and most beautiful terrain in the United States.

Most of the Gallatin Canyon Area is public land administered by the U. S. Forest Service. Because of its accessibility, land ownership and high quality recreational opportunities, the Gallatin enjoys a reputation of being one of the finest outdoor recreation areas in the United States.

In the Gallatin, hunters pursue elk, deer, moose, highhorn sheep and mountain goat. Elk hunting here is nationally renowned and attracted over 2,300 hunters for the 1970 hunting season. Elk wintering close to the highway attract numerous visitors to the canyon.

As the popularity of snowmobiling has increased, favorable snow conditions in the Gallatin Canyon have attracted participants of this sport. The Snowmobile Club in Bozeman, with the assistance of the Montana Fish and Game Department and Gallatin National Forest, has developed the Big Sky Snowmobile Trail which winds south through the mountains from Bozeman to West Yellowstone.

The Gallatin River which traverses the entire canyon is a blue-ribbon trout stream providing angling for brown, rainbow and some brook trout. In the upper reaches of the river and in tributary creeks, fishermen take native cutthroat. In high mountain lakes they may find golden trout.

Other summer outdoor activities include camping and picnicking in one of many campgrounds established by the Forest Service, and hiking on mountain trails.

SOIL ASSOCIATIONS

1. BIGEL-HOBACKER ASSOCIATION

This soil association is along Highway 191. It is almost continuous from the mouth of the Gallatin Canyon to the Yellowstone Park boundary. It is on the stream terraces and fans adjacent to the Gallatin River and its main tributaries. The soils have formed from alluvium. The terraces have smooth to irregular surfaces with 1 to 5 percent slopes. Fan slopes are from 5 to 35 percent. Vegetation includes bunch grasses, shrubs and forbes. Elevation is between 5,200 and 6,700 feet. Mean annual precipitation is 20 to 30 inches. 11 to 20 inches of which comes in the form of snow. Frost usually occurs at least once during all of the summer months. This association comprises about 8,800 acres, 75 percent of the survey area.

Gravelly alluvial soils are on the first and second terraces above the streams, with those on the first terraces subject to annual flooding. Bigel and Bearmouth soils are closely associated on the second and third terraces. Bearmouth soils occur as narrow, low, very gravelly ridges among the Bigel soils. Landscapes are smoother and less channeled than the lower terraces. Hobacker soils occupy short fans of 5 to 35 percent slopes between the uplands and the stream terraces. Michelson soils are on the highest valley terraces, bordering the uplands. This association, being along the river and the highway, is used intensively for picnicking, camping, as a fishing access and as base headquarters for horseback riding, hiking, hunting, snowmobiling and other recreational uses. The majority of residential development in the Gallatin Canyon area, dude ranches and business establishments are built on this association. Management problems are created by potential pollution of surface and ground water from sewage and garbage. Spring flooding of the Gallatin River also presents some hazards and debris problems.

Bigel Soils are well drained. They have a dark grayish brown gravelly loam surface layer 8 to 15 inches thick, a brown very gravelly or cobbly clay loam subsoil and a sand and gravel substratum. Depth to sand and gravel ranges from 24 to 50 inches. They are free of lime to depths of 20 inches or more. The clay loam subsoil has from 35 to 55 percent gravel and cobble. These soils have moderately slow permeability in the upper part of the profile and rapid permeability in the lower part. Bigel soils are used for native range, dwelling sites, picnicking and camping sites. They represent about 25 percent of the association.

Bearmouth Soils are excessively drained. They are very dark grayish brown, gravelly loams with sand and gravel at shallow depths. The profile usually becomes very gravelly (over 35% gravel) at depths of 5 to 15 inches. Depth to clean sand and gravel ranges from 10 to 30 inches. Permeability is moderate in the surface few inches, becoming rapid below. Effective rooting depth of these soils is usually less than 20 inches. They are used for native range. They represent about 10 percent of the association.

Gravelly Alluvial Soils occur near the Gallatin River and its tributaries. Some of them have seasonal high water tables and others are flooded annually. Landscapes vary from nearly level to undulating and irregular. Soils are gravelly to very gravelly and include cobbly loams to loamy sands. Depth to clean sand and gravel ranges from 4 to 40

inches. Riverwash in 1 to 5 acre areas is included with the gravelly alluvial soils. They are used primarily for native range; however, some areas provide camping and picnicking grounds. They represent about 20 percent of the association.

Hobacker Soils are well drained. They have a very dark brown surface layer, 16 to 40 inches thick, and a very gravelly or cobbly subsoil and substratum. Coarse fragments range throughout the profile from 35 to 70 percent. There are accumulations of secondary lime, as nodules and streaks, beginning at 7 to 10 inches below the surface. Textures throughout the profile are loam or clay loam which are moderately permeable. Hobacker soils are developed in alluvium on fans at the mouth of side creeks and intermittent drainageways, and on footslopes below the uplands. Associated with the Hobacker soils on these positions is another soil that differs from Hobacker by being lime free to 36 inches or more. Native range and dwelling sites are the major uses. Hobacker represents about 25 percent of the association.

Michelson Soils are well drained soils and are over 40 inches deep. They have a 6 to 10 inch till very dark brown surface, a brown, prismatic and blocky clay loam subsoil and strongly calcareous, loam substratum. The largest area of these soils is on the high stream terraces, bordering the uplands. This association, being along the river and the highway, is used intensively for picnicking, camping, as a fishing access and as base headquarters for horseback riding, hiking, hunting, snowmobiling and other recreational uses. The majority of residential development in the Gallatin Canyon area, dude ranches and business establishments are built on this association. Management problems are created by potential pollution of surface and ground water from sewage and garbage. Spring flooding of the Gallatin River also presents some hazards and debris problems.

Bigel Soils are well drained. They have a dark grayish brown gravelly loam surface layer 8 to 15 inches thick, a brown very gravelly or cobbly clay loam subsoil and a sand and gravel substratum. Depth to sand and gravel ranges from 24 to 50 inches. They are free of lime to depths of 20 inches or more. The clay loam subsoil has from 35 to 55 percent gravel and cobble. These soils have moderately slow permeability in the upper part of the profile and rapid permeability in the lower part. Bigel soils are used for native range, dwelling sites, picnicking and camping sites. They represent about 25 percent of the association.

Bearmouth Soils are excessively drained. They are very dark grayish brown, gravelly loams with sand and gravel at shallow depths. The profile usually becomes very gravelly (over 35% gravel) at depths of 5 to 15 inches. Depth to clean sand and gravel ranges from 10 to 30 inches. Permeability is moderate in the surface few inches, becoming rapid below. Effective rooting depth of these soils is usually less than 20 inches. They are used for native range. They represent about 10 percent of the association.

Gravelly Alluvial Soils occur near the Gallatin River and its tributaries. Some of them have seasonal high water tables and others are flooded annually. Landscapes vary from nearly level to undulating and irregular. Soils are gravelly to very gravelly and include cobbly loams to loamy sands. Depth to clean sand and gravel ranges from 4 to 40

slopes. Vegetation consists mostly of lodgepole pine and Douglas fir with an understory of pine grass, elk sedge and shrubs. This association is between 6,000-8,000 feet elevation. Mean annual precipitation is 25 to 50 inches; 15 to 40 inches of this comes in the form of snow. It is common to have a frost during each of the summer months. This association consists of about 20,000 acres, or approximately 17 percent of the survey area. Loberg soils comprise about 80 percent of the association. Soils resting on bedrock at depths less than 20 inches, rock outcrop, rock rubble and other miscellaneous soils make up about 20 percent. Logging operations on this association are severely hampered on slopes that exceed 30 percent. Very stony and rock outcrop areas also present some difficulties in the placement and building of logging roads. Soil losses can be held to a minimum by proper location and gradient of these roads.

Loberg Soils are well drained. A typical profile under a thin layer of forest litter consists of a light gray or light grayish brown loam over a thick brown clayey subsoil that is gravelly, cobbly and stony. The substratum is a very gravelly to stony clay loam. They are noncalcareous to depths of 3 feet or more. Coarse fragments increase with depth from about 35% in the upper part of the profile to over 60% in the substratum. There are stones on the surface and throughout the profile. These soils are slowly permeable. They are used primarily for timber products. They represent about 80% of the association.

Garlet Soils are similar to the Garlet soils described in Association 3. They represent about 10% of the association. **Other Soils** in this association are very shallow soils over bedrock, rock outcrop, rock rubble and miscellaneous soils along creek bottoms, representing about 10% of this association.

3. GARLET ASSOCIATION

This forested association of soils is on steep mountainous slopes. The landscape consists primarily of a series of ridges and V-shaped canyons. Slopes range from 8 - 60 percent but are dominantly between 15 and 50 percent. The soils are developed in residual material from quartzite, argillite and hard sandstone, either in place or in these same materials that have moved down slope by gravitational creep. There is a large area of these soils between the North and Middle Fork of the West Fork drainage and in many of the other major tributaries of the Gallatin River. Vegetation is primarily lodgepole pine and Douglas fir with an understory of pine grass, elk sedge and shrubs. This association occurs at elevations between 7,200 and 8,100 feet. Precipitation is from 30 to 60 inches annually; 20 to 50 inches of this comes in the form of snow. The association comprises about 4,800 acres, or approximately 4.1 percent of the survey area. The association consists of about 65 percent Garlet soils, 20 percent of a soil that is only 20 to 40 inches deep over bedrock but is otherwise similar to Garlet, and forested soils developed in till. Other miscellaneous soils make up the balance. Garlet soils are on the long slopes between the ridges and the drainageways. The shallow variant of Garlet is commonly on the upper slopes near the ridges. The ridges, points of hills and down slope knobs are usually occupied by shallow and very shallow soils over bedrock. The surface layer of all these soils is predominantly an angular gravelly

loam. However, stony loam areas are not uncommon. In the profiles of all these soils, content of rock fragments increases with depth to around 60 to 80 percent, being highest just above the bedrock. This is a woodland association. Its primary uses are for forest products and watershed. Logging operations are severely hampered on slopes over 30 percent and in rock outcrop or very stony areas. Soil losses can be held to a minimum by proper location and gradient of logging roads.

Garlet Soils are well drained. A typical profile under a thin layer of forest litter consists of a thick light gray (A2) layer, grading to a light yellowish brown and light gray mixed (A & B) horizon which further grades to a (B & A) horizon with an increase of yellowish brown spots and a decrease of light gray with depth. The mixed A and B horizons break at depths below 12 to 20 inches. Profile texture ranges from loam to light clay loam. Angular gravel, cobble and stone increases throughout the profile from around 20% in the surface to about 70% in the substratum. These are noncalcareous, moderately permeable soils. Fractured bedrock occurs at depths ranging from 50 to 80 inches. They are primarily used for timber production and watershed. They represent about 60% of the association.

Garlet Shallow Variant Soils rest on fractured bedrock at depths of 20 to 40 inches. Otherwise, they have similar soil colors, textures and sequence of horizons as Garlet soils. They usually have a higher percent of coarse fragments, higher in the profile, than Garlet and are shallower to bedrock. Their primary use is for timber production and watershed. They represent about 20% of the association.

Loberg Soils in this association are similar to those described in Association 2. They represent about 10% of the association. **Other Soils** in this association consist of very shallow soils, clay areas, sandy areas, rock outcrop and miscellaneous soils along creeks. They represent about 10% of the association.

4. TETON - CHEADLE ASSOCIATION

This grassland association of soils is primarily on mountain "park" areas. Landscapes are generally smooth but may include some ledges and outcrops areas downslope from the rounded ridges. Dominant slopes are between 10 and 40 percent. This association occurs at elevations between 5,600 and 8,400 feet. Annual precipitation ranges from about 20 inches to near 60 inches at the higher elevations; 11 to 40 inches of this is in the form of snow. Frost usually occurs at least once during each of the summer months at elevations above 6,000 feet. Vegetation consists of Idaho and rough fescues, mountain brome, shrubby cinquefoil, bluegrasses and forbes. This association comprises about 4,800 acres, or approximately 4.1 percent of the survey area. The association consists of about 65 percent Garlet soils, 20 percent of a soil that is only 20 to 40 inches deep over bedrock but is otherwise similar to Garlet, and forested soils developed in till. Other miscellaneous soils make up the balance. Garlet soils are on the long slopes between the ridges and the drainageways. Hobacker and Adel soils are most common along creeks. Rock outcrop is usually associated with the Cheadle soils along ridges and points of hills in areas of less than an acre in size. This association is used for grazing of livestock and wildlife. Elk are the prime users of this association in the Porcupine and Tepee Creek

drainages and also in the upper portions of Portal, Beaver, Taylor Fork and other drainages. Proper range management practices and wildlife control measures will maintain and improve the vigor and amount of the more desirable species of grass.

Teton Soils are well drained. A typical profile has 7 to 12 inches of very dark brown or black loam surface layer, a grayish brown or yellowish brown, prismatic and blocky structured, light clay loam subsoil and a calcareous loam substratum that rests on partially weathered sandstone. Depth to bedrock is usually between 30 and 40 inches. Gravel and cobble content throughout the profile ranges from 5 to 30%. These are moderately permeable soils with medium to moderately slow runoff. They represent about 65% of the association. **Cheadle Soils** are excessively drained. A typical profile has a thin, dark grayish brown to very dark grayish brown gravelly loam surface layer, a weak blocky structured, grayish brown, gravelly loam subsoil and a calcareous gravelly to very gravelly loam substratum. Fractured hard bedrock occurs within 20 inches of the surface but is usually at 10 to 18 inches. Runoff is rapid. They represent about 20% of the association. **Other Soils** in this association consist of Hobacker and Adel soils (refer to Association 1 for description) clay areas, rock outcrop and other miscellaneous soils along creeks. Other soils represent about 15% of the association.

5. MISCELLANEOUS STEEP MOUNTAINOUS LANDS

This association consists of miscellaneous lands, rockland, rock outcrop and rock rubble on steep and very steep canyon sidewalls and ridges. The majority of this association is located along the Gallatin River Canyon. Miscellaneous lands consists of soils of variable textures and variable depths over bedrock. Content of rock fragments in these soils varies from those with only a few pebbles in them to those that are very cobbly and stony. Vegetation consists mostly of lodgepole pine and Douglas fir; however, there are grassland areas and some mixed timber and grass areas. Timber growth is quite variable, ranging from a few scattered trees to some dense groves. The thicker stands are on north-facing slopes and along coulees. Logging on this association is prohibited by the very steep slopes except on the lower, less sloping fans and footslopes. Grazing is primarily by wildlife. This association comprises about 25,000 acres or approximately 21 percent of the survey area. The shallower soils usually occur on convex slopes along ridges. The deeper soils are on fans and footslopes at lower elevations. About 25 percent of the association consists of rock outcrop and rock rubble. They occur at all levels in the landscape; however, rock outcrop is dominant on the upper slopes. Limestone rockland is most common along the Gallatin River Canyon, however, rockland at the head of side drainages at higher elevations consists of older granitic and andesitic rocks. Much of the soil on the steep slopes has formed in material moved down slope by gravitational creep. Soils on the lower slopes are developed mostly in local colluvial and alluvial materials.

6. TETON - GARLET ASSOCIATION

This is a complex association of Teton soils, under grass, and Garlet soils, under timber. They are on hilly to mountainous landscapes. Slopes range from

15 to 50 percent. Grassland vegetation consists of Idaho and rough fescues, mountain brome, bluegrasses, forbes and shrubs. Timber consists mostly of lodgepole pine and Douglas fir with an understory of pine grass, elk sedge, wild rose and other shrubs. Most of this association is between elevations of 6,500 and 8,000 feet. Annual precipitation is between 25 and 40 inches; 15 to 20 inches of this comes in the form of snow. This association comprises about 12,000 acres, approximately 10 percent of the survey area. Teton and Garlet soils are about equal in percent of the entire association; however, either soil may comprise from 25 to 60 percent of a particular area. Combined, they make up about 80 percent of the association. Rambler, Cheadle and glacial till soils similar to Leavitt and Loberg make up about 20 percent. Teton and Cheadle soils are most common on the upper south-facing slopes and convex areas respectively. The forested Garlet, Rambler and Loberg soils occupy the long slopes between the ridges and drainageways. Soil profiles for Teton, Cheadle and Garlet soils are similar to those described for these soils in Associations 3 and 4. This association is used for timber production, watershed and wildlife. Elk are prime users of the Teton and Cheadle "park" areas.

7. GARLET - LOBERG ASSOCIATION

This soil association is on steep and very steep mountainous slopes. Shallow ridges separated by deep cut canyons characterize the landscape. Rock outcrop, rock rubble and landslide areas are common. This association is at elevations of 6,000 to 8,500 feet. Annual precipitation ranges from 25 to 50 inches; 25 to 40 inches of this comes in the form of snow. Vegetation consists of lodgepole pine and Douglas fir with an understory of pine grass, elk sedge, and shrubs. This association comprises about 27,300 acres, or approximately 23.2 percent of the survey area. The major soil in this association is Garlet very gravelly to stony loam. It comprises about 65 percent: Loberg stony soils, 20 percent; Teton, Cheadle and Garlet soils, 15 percent. Garlet occurs on the long steep mountain slopes between the ridges and the drainageways unless interrupted by the occurrence of Loberg soils on the lower portion of the landscape. These forested soils which developed in till also occur at the head of drainageways, immediately below steep mountain cirques. This association is primarily used as watershed; however, some logging is done at lower elevations as some of the less sloping areas. Wildlife also graze the "park" areas and grass-shrub areas along drainageways. **Garlet Soils** in this association consist of Garlet and Garlet Shallow Variant soils. These soils are described in Association 3.

Loberg Soils have similar profiles to those described in Association 2. **Other Soils** in this association consist of rock outcrop and rock rubble, very shallow soils, landslide areas, miscellaneous soils and steep areas along drainageways.

8. LEAVITT - HANSON ASSOCIATION

This is a grassland association of soils on undulating to steep glacial till uplands. Landscapes are complex and typically glacial till "kettle and kame" topography. Most of the slopes are between 8 and 35 percent. This association commonly occurs midway between the forested till soil areas and the soils of

the valley terraces below. It is at elevations of 5,400 to 6,700 feet. Annual precipitation is 20 to 30 inches; 11 to 20 inches of this comes in the form of snow. Frost can be expected to occur at least once during each of the summer months above 6,000 feet. Vegetation consists mostly of Idaho and rough fescues, bluegrasses, forbes, big sage and other shrubs. This association comprises about 6,300 acres, or approximately 5.4 percent of the survey area. The largest areas of this association are located on Porcupine, Tepee, West Fork and Beaver Creek drainages. Leavitt stony loam is the dominant soil type; however, there are areas of cobbly loam and some areas free of coarse fragments in the surface layer. The latter is most common on the north-facing slopes of the Porcupine Creek drainage. In this area the Leavitt soils have thicker, dark colored surface layers than is modal for the series. Leavitt soils consistently occupy the sloping lands between the ridges, or knobs, and the drainageways and concave areas. Hanson very cobbly and stony soils are on the knobs and ridges. The highest concentration of cobbles and stones is associated with this soil. Adel, Michelson or Hobacker soils occur throughout the association. Some seeped soil areas occur along some drainageways. An occasional small intermittent lake is trapped in the undulating in the upper profile than Rambler stony loam. The stony loam type has from 20 to 50% sub-angular cobble and stone in the surface layers compared to 35% or more in the very cobbly type.

Other Soils in this association are Garlet, Loberg, shallow soils over bedrock, rock outcrop and miscellaneous soils along drainageways. Other soils comprise about 20 percent of the association.

Leavitt Soils are well drained. A typical profile is over 5 feet deep. It has a dark brown or very dark brown, loam, surface layer, 8 to 15 inches thick, and a dark grayish brown or brown cobbly subsoil of heavy clay loam to light clay texture. The substratum is gravelly to very gravelly and cobbly clay loam. They are lime free to depths of 20 to 36 inches becoming strongly calcareous below. Coarse fragments in the surface layer range from 0 to 30%, increasing to 35 to 60% through the subsoil and substratum. Permeability is moderately slow. Effective rooting depth is more than 36 inches. **Hanson Soils** are well drained. A typical profile is over 5 feet deep. It has a 10 inch very dark brown or black, non-calcareous, very cobbly loam surface layer; a dark grayish brown, calcareous, very cobbly loam subsurface horizon and a nearly white, strongly calcareous, very cobbly to very stony loam subsoil and substratum. Throughout the association the Hanson soils have surface layers of loam gravelly to very gravelly loam, cobbly to very cobbly loam and stony to very stony loam. Very cobbly and stony loam is dominant. Thickness of the dark colored surface layer varies from 7 to 16 inches. Content of coarse fragments throughout the profile varies from 35 to 60%. They usually increase with depth. **Other Soils** in this association are Adel, Hobacker and Michelson soils which are similar to those described in Association 1. Other soils include miscellaneous, seeped and poorly drained soils along drainageways.

9. RAMBLER ASSOCIATION

This association occupies undulating, steep and very steep mountainous landscapes. It is at elevations of 8,000 to 9,000 feet in the vicinity of Lone Mountain and Andesite Point. Slopes range from 15% on the lower elevations to 60%

on the upper slopes, just below the rock rubble of Lone Mountain and Andesite Point. Annual precipitation ranges from 40 to 60 inches of which 30 to 50 inches comes in the form of snow. Vegetation is primarily lodgepole pine with an understory of pine grass and shrubs. This association comprises about 2,600 acres, or approximately 2.2 percent of the survey area. Rambler very cobbly loam and Rambler stony loam types comprise about 80% of the association. The very cobbly Rambler soils are on the steepest slopes. The stony Rambler soils are on the undulating and less sloping lower portions of the association. This association is important primarily for its watershed value. Logging has been limited to the lower slopes.

Rambler Soils are deep. They are non-calcareous and well to excessively drained. A typical profile under a thin layer of forest litter has a brown to very pale brown surface layer of very cobbly to stony loam. It has a platy structure with bleached silt and sand grains concentrated on the top of plates. The profile below is similar in color but lacks structure and is of loam or sandy loam texture. Content of coarse fragments in gravel to stone size in these soils varies from 35 to 70% by volume in the 10 to 40 inch portion of the profile, and usually increases with depth. Rambler very cobbly loam soils have a higher content of coarse fragments in the upper profile than Rambler stony loam. The stony loam type has from 20 to 50% sub-angular cobble and stone in the surface layers compared to 35% or more in the very cobbly type.

Other Soils in this association are Garlet, Loberg, shallow soils over bedrock, rock outcrop and miscellaneous soils along drainageways. Other soils comprise about 20 percent of the association.

10. LEAVITT - LOBERG ASSOCIATION

This soil association is a complex of grassland and forested soils developed in glacial till on undulating to hilly and mountainous uplands. The four main areas of occurrence are between Beaver and the West Fork Creeks, along Porcupine and Tepee Creek drainages and also south of the mouth of Cinnamon Creek. It occurs at elevations ranging between 6,000 and 6,500 feet. Slopes range from 8 to 40%. Much of this association has a "kettle and kame" topography. Vegetation on the Leavitt soils consists of Idaho fescue, rough fescue, mountain brome, shrubby cinquefoil, bluegrasses and forbes. Lodgepole pine and Douglas fir are the primary vegetation on the Loberg soils. Annual precipitation ranges from about 20 to 40 inches, of which 11 to 25 inches comes in the form of snow. It is common to have a frost during each of the summer months. There are approximately 5,600 acres in this association comprising about 4.8 percent of the survey area.

Leavitt Soils in this association are similar to the Leavitt soils described in Association 8. They represent about 40 percent of this association.

Loberg Soils in this association are similar to the Loberg soils described in Association 2. They represent about 40 percent of this association.

Garlet Soils are similar to the Garlet soils described in Association 3. They represent about 10 percent of this association.

Other Soils include wet soils in pot holes, and along drainageways, very shallow soils and rock outcrop. They represent about 10 percent of this association.

DEFINITION OF SELECTED USES

FOUNDATIONS FOR LOW BUILDINGS: Interpretations indicate limitations for construction and maintenance of homes and small buildings less than three stories high. They are affected by soil characteristics such as frost heave potential, shrink-swell, slope, depth to bedrock, stoniness, texture, salinity, compaction, and flood hazard. (Limitations for on-site sewage disposal is rated separately.)

SEPTIC TANK FILTER FIELDS: Successful operation of the system depends on the ability of the soil to absorb and filter the liquid or effluent passed through the tile field. Filter fields are influenced by the ease of downward movement of effluent through the soil. Soils with slow permeability are rated severe. Other soil properties that effect septic tank filter fields are flooding hazard, depth to bedrock, seasonal high ground water and slope. Clean sands and gravels with rapid permeability may constitute a hazard for ground water contamination.

ROAD AND PARKING LOCATION is based on those features that affect performance for the location of highways, streets and parking areas. The main factors considered are depth to water table, flooding hazard, depth to bedrock, susceptibility to frost heave, shrink-swell potential, compaction characteristics, bearing strength, and slope.

LAWNS AND LANDSCAPING: The soil is rated on the assumption it will be used for lawn turf, shrubs and trees without need for adding topsoil for good establishment and that irrigation is provided. Soil characteristics affecting

this use are depth to seasonal high water table, depth to bedrock or gravel, stoniness, surface soil texture, salinity and slope.

CAMP AREAS are considered to be used intensively for tents, truck campers and small camp trailers with the accompanying activities of outdoor living. It is assumed that little site preparation will be done other than shaping and leveling for tents and parking areas. The soils should be suitable for heavy foot traffic by humans and for limited vehicular traffic. Permeability, texture, slope, depth to water table, flooding hazard and stoniness affect suitability for this use. Soil suitability for growing and maintaining vegetation is not rated but is an item to consider in final evaluation of the site. (See ratings for lawns and landscaping.)

PICNIC AREAS are considered to be extensively used as park-type picnic grounds. It is assumed that most vehicular traffic will be confined to access roads and parking areas. Permeability, slope, flood hazard, surface soil texture and surface stoniness affect suitability for this use. Soil suitability for growing vegetation is not rated but is an item to consider in final evaluation of the site.

PLAYGROUNDS for recreation applies to soils that are to be used intensively for organized games such as football, baseball, volleyball, horseshoes and other similar organized games.

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