LAND-CAPABILITY CLASSIFICATION OF THE LAKE TAHOE BASIN, CALIFORNIA-NEVADA

A Guide for Planning

By
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in cooperation with the
Tahoe Regional Planning Agency

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Foreword

Since 1970, the Forest Service and the Tahoe Regional Planning Agency have cooperated in a joint environmental land use planning study of the Lake Tahoe Basin on the California-Nevada border. As part of this program, criteria were developed for classifying lands – according to their inherent physical capacity to provide for use without endangering achievement of the goals established by the Bi-State Compact (P.L. 91-148) for protecting the environmental qualities of the basin.

Since the systematic approach to determination of land capability may be useful to others who have planning responsibilities, the approach used at Lake Tahoe has been summarized in this report.

The principles applied at Lake Tahoe in determining the physical capability of land to provide use appear to have general applicability to land use planning in other wildland areas. Objectives may differ, but the fundamental knowledge of how certain units of land naturally function within the eco-system and their tolerance to disturbance by man's activities should be clearly understood before making decisions regarding land use. The tradeoffs necessary to accommodate certain land uses can then be publicly weighed in the proper physical perspective for land use planning purposes. Social and economic aspects are then brought in to complete the land use planning process.

DOUGLAS R. LEISZ
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Preface

Much of the growth that has partially engulfed the Lake Tahoe basin has taken place with little regard for the natural capabilities and limits of the land and water resources. In places, uncontrolled recreation development, road construction, urbanization, and similar activities have created serious environmental problems. A review of planning experience suggests that many of these problems have been aggravated by failure to recognize that they are inherently regional in scope and cannot be satisfactorily solved on a local basis.

As competition increases for use of limited and interrelated resources, as the more gently sloping lands become used more intensively, and as development activities extend further into rugged terrain, these planning deficiencies become more important. Prospects for increased resource use emphasize the need for better ways to identify the most suitable areas for various intended uses or combinations of uses. Fitting each use to the proper terrain should more effectively protect soil and water resources, wildlife habitat, and scenic beauty, as well as increase productivity and financial returns, and stabilize the economy.

Until recently, it was unrealistic to consider land capability in forest land classification, because the basic data from which to assess capability were lacking. Thus, it was not possible to develop criteria usable in wildland planning. Although knowledge in this area of land use planning is still incomplete, we now have sufficient experience in specific situations to recognize where certain types of land development cannot be carried out without serious environmental damage. To the extent that these critical areas can be identified and integrated with socioeconomic conditions and the objectives for the planning area, the utility of the land use plan can be improved.

During the period January to June 1971, the U.S. Forest Service, in cooperation with the Tahoe Regional Planning Agency, completed a reconnaissance-level land capability study of the Lake Tahoe basin. Soil and geomorphic information was compiled on maps at a scale of 2 inches to the mile. From these data, a land capability map was prepared for the basin and used in compiling the generalized Land Capabilities Map of the Lake Tahoe Basin (pocket) included with this report. This map is intended for use in broad resource allocation planning until such time as detailed land capability studies may be needed.

Acknowledgements

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Contents

	Page
FOREWORD	iii
PREFACE	v
Acknowledgments	v
ABSTRACT	1
INTRODUCTION	1
The Lake Tahoe Basin	3
Land Capability Defined	4
Outline of Analysis Procedure	5
FACTORS USED IN RATING CAPABILITY	5
Soil Type	5
Erosion Hazard	5
Hydrologic-Soil Group	7
Soil Drainage	9
Rockiness and Stoniness	12
Geomorphic Setting	14
A. Glaciated Granitic Uplands	14
B. Glaciated Volcanic Flowlands	16
C. Streamcut Granitic Mountain Slopes	16
D. Streamcut Volcanic Flowlands	17
E. Depositional Lands	17
F. Oversteepened Slopes	17
Hazard Rating of Geomorphic Units	17
COMBINED CAPABILITY RATING	18
RECOMMENDED USE	18
Lands That Should Remain in Their Natural Condition	22
Lands That Are Permissive to Certain Uses But Not Others	23
Lands That Are Most Tolerant to Urban-Type Uses	24
Allowable Impervious Cover	24
APPLICATION OF THE CLASSIFICATION TO PLANNING	25
LITERATURE CITED	26
APPENDIX: CAPABILITY RANKING BY SOIL TYPE	29

Illustrations

Page

Land capabilities map of the Lake Tahoe basin . . . . . In pocket

Figure 1. Development of steep, unstable land near Rubicon Point on the California side of Lake Tahoe 4

2. Index map of northern California and adjacent part of Nevada, showing area of this study 5

3. Soil erosion hazard groups related to land capability in the Lake Tahoe basin 8

4. Hydrologic-soil groups related to land capability in the Lake Tahoe basin 10

5. Soil drainage related to land capability in the Lake Tahoe basin 13

6. Rockiness and stoniness related to land capability in the Lake Tahoe basin 15

7. Geomorphic groups related to land capability in the Lake Tahoe basin 19

8. Land areas in several capability classes around the south shore of Lake Tahoe 21

9. Subclass 1a land severely affected by erosion 22

10. Typical subclass 1b meadow land in the upper Truckee River valley 22

11. Subclass 1c land in background 23

12. Class 4 land showing typical vegetation 23

13. Class 6 land in El Dorado County 24

Tables

Page

Table 1. Lake Tahoe basin land area classified by inherent erosion hazard 7

2. Lake Tahoe basin land area classified by hydrologic-soil group 9

3. Geomorphic units, Lake Tahoe basin 16

4. Basis of capability classification for Lake Tahoe basin lands 20

5. Lake Tahoe basin land area classified by capability 20

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ABSTRACT

The prospect of increased land development in the Lake Tahoe basin emphasizes the need for better criteria for planning and executing development if damage to the water resource and ecosystem is to be prevented. To fill the need, land capability classes were established to guide regional planning and development. Land tolerance was used as the principal measure of capability. Two types of factors were used to rate capability or tolerance: soil type and geomorphic setting. The type and intensity of land use consistent with natural limitations are suggested for each capability class. Limits on land-surface modification are expressed as a percentage of each area that can be used for impervious cover.

INTRODUCTION

Since the late 1950's the Lake Tahoe basin has been subjected to rapid development[1] for various purposes. This expansive growth has been responsible for many improper land development procedures, including failure to recognize hydrologic and topographic limitations, unnecessary and widespread destruction of vegetal cover, realignment and pollution of streams, encroachment on flood plains, and disruption of natural drainage. Because the soils in this area are generally lacking in humus and other soil-binding and moisture-holding materials, there is great erosion potential. Consequently, local streams are extremely susceptible to damage from sedimentation. The sediment carried into the lake provides substrate anchorage for aquatic weeds and also supplies nutrients that encourage the growth of algae. Flooding problems have been aggravated by uncontrolled runoff from denuded areas and impervious surfaces. The problem has been widely discussed and illustrated (Goldman 1967, U.S. Department of Agriculture 1972). Deterioration has reached a point where human activities that induce sedimentation are probably the chief threat to environmental quality in the basin.

Man-induced erosion and its product, sediment, represent a loss of control over water in its contact with soil. The maintenance or reestablishment of hydrologic conditions that will insure control of water is a major objective of resource management in the Tahoe basin. To achieve this, the forest lands on which the waters originate must be allowed to function naturally to regulate streamflow and control sediment. All resource uses and activities must be compatible with a scientifically sound evaluation of the hydrologic limits of land use. Beyond these limits, productivity declines because erosion is accelerated and the usefulness of streamflow diminishes. The capacity of the land to tolerate disturbance in the form of use for timber, forage, recreation, and housing, and still maintain the normal stability of the soil and specific characteristics of streamflow is determined by physical and biological phenomena.

Some forest areas clearly can tolerate severe disturbance and yet remain comparatively stable. Other areas may become highly unstable after only slight disturbance. Conse-

[1] *Throughout this paper, the term "development," or "land development," is used in a general sense to denote all forms of development herein discussed, including recreation, forestry, residential, and urban.*

Figure 1. – Steep, unstable land has been developed near Rubicon Point on the California side of Lake Tahoe. Removal of vegetation has exposed soil to greatly accelerated erosion. In addition, the streets and buildings intercept and concentrate runoff, greatly increasing its erosive force. (Soil Conservation Service)

quently, the nature and intensity of the disturbance process are not in themselves sufficient explanations of land stability. It is evident that the many differences observable in the way particular areas in the Tahoe basin react to use are related primarily to physical variations in the environment – climate, topography, geology, and soils.

The implications of this fact deserve serious attention. In many areas nature has balanced physical variations in the local environment with differing vegetation covers, resulting in stable slopes. Such ecological balances are often extremely delicate. Failure to recognize the nature of the balance, and consequently the limits of vegetative disturbance permissible before such balances are upset, has led to land development in places where only ecologic damage can be expected (*fig. 1*). Such damage can only be avoided if the hazard can be evaluated in advance of disturbance. Once the hazard is recognized, high hazard areas can be eliminated from development plans. If they must be included, then development can proceed with use of appropriate structures and construction techniques to minimize the impact of development. Specification of such measures is presented in numerous publications (Environmental Protection Agency 1971, Federal Water Pollution Control Administration 1970, and Packer 1967) and therefore is beyond the scope of this paper. In any approach, however, the primary need is for classification of unstable areas according to the level of use they can tolerate.

To fill the need, a series of capability classes were defined, and land development practices applicable to each class were identified. The system was designed to provide an

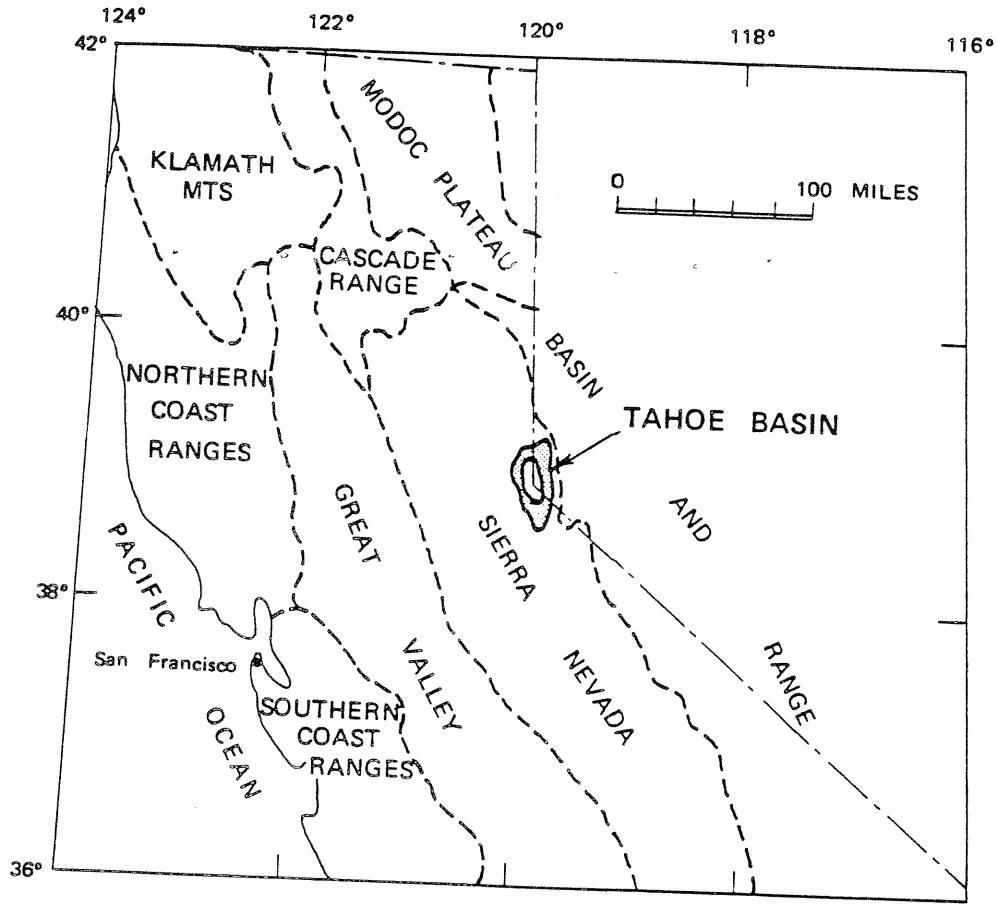

Figure 2. – Index map of northern California and adjacent part of Nevada, showing area of this study.

objective basis for planning and executing development so that soil and water resources will be protected more effectively than they have been in the past. This report describes the methods used in establishing the classification and clarifies the meaning and implications of the class designations shown on the pocket map.

The Lake Tahoe Basin

The Lake Tahoe basin lies on the east side of the Sierra Nevada physiographic province, between elevations of 6,200 and 10,000 feet (*fig. 2*). The basin includes about 500 square miles, with 192 square miles, or 38 percent, covered by the waters of Lake Tahoe.

The basin is underlain predominantly by granitic rocks related to the rocks found throughout the Sierra Nevada. In the northern section, volcanic rocks overlie the granite. Regional uplift, faulting, and erosion have resulted in a rugged topography characterized by steep slopes and narrow canyons. Alpine glaciation on the western side of the basin has produced steep-sided troughs and serrated mountain tops. Those parts of the northern and eastern sections not glaciated consist partly of mountains deeply incised by narrow stream valleys, and partly of terrain that is gently rolling to hilly. The southern portion of the basin, as well as lakeshore areas not dominated by bedrock, consist primarily of glacial moraine and outwash terrain.

Climatic conditions vary widely within the basin as a result of differences in elevation and exposure. Summers are dry and cool, and winters are wet and cold. Average annual precipitation ranges from more than 80 inches at the highest elevations to about 25 inches at

the lowest elevations. About 80 percent of the annual precipitation occurs between October and April. Because of below-freezing temperatures, much of the precipitation during the winter months is snow. Heavy winter rains also occur, however, and often cause flooding, especially when they coincide with the melt from earlier snowfalls. Intense summer thunderstorms also cause localized flooding.

The mean annual temperature of Tahoe City (elev. 6,230 ft.) is 42°F, and the mean monthly temperature ranges from 25°F in January to 61°F in July. The high elevation and cool temperatures result in a short growing season – an average of only 70 to 120 frostfree days per year.

Vegetation includes desert, montane, and alpine species typical of the eastern slope of the Sierra. Pine and fir forests, which cover the greater part of the basin, were heavily logged between 1860 and 1900 when demand for lumber for the Nevada silver mines was high. After regrowth, however, the basin again contains generally good stands of conifers between the lake level and 8,000 feet. Considerable areas are also covered by brush and grass.

Soils of the Lake Tahoe basin are complex and show considerable local variation owing to steep topography and highly varied climate, vegetation, and parent material. Certain soil characteristics are dominant, however. On the nonglaciated slopes, soils are generally immature and show little evidence of profile development. They are shallow (3 feet or less) and rocky, with gravelly loamy sands overlying impervious bedrock. Being coarse textured and poorly aggregated, they are readily susceptible to erosion – especially when exposed bare on steep slopes. About half of the soils in the basin are on slopes greater than 20 percent. Low waterholding capacities, inherent infertility, and a short, dry growing season make revegetation extremely difficult.

In addition to urbanization, repeated logging, overgrazing, and fires have damaged the moisture storage and infiltration capacities of the soil mantle on many sites in the Lake Tahoe basin. As a consequence, many areas have low-density vegetation, bare soil, and exposed rock, with stream channels choked with eroded material.

Land Capability Defined

Systematic classification of land for various purposes is not new. It has been standard practice in managing agricultural lands for at least a third of a century (see Klingebiel and Montgomery 1961, and Wohletz and Dolder 1952). Resource managers are accustomed to thinking of sustained-yield management in such terms as allowable timber harvest (Weitzman and Trimble 1955) and allowable numbers of livestock on range lands (U.S. Department of Agriculture 1962). Studies of these allowable limits have proved useful, and the same patterns of thought have been applied to wildlife (Wertz 1966) and recreation (Wagar 1964).

Land classification is being increasingly used by Federal and State agencies as a basis for land-use planning and policy formulation. Examples of this approach are provided by Bailey (1971a), Hills (1966), McCormack (1971), McHarg (1969), Patri et al. (1970), University of Pennsylvania (1968), and Wikstrom and Hutchison (1971).

Although land capability is frequently mentioned in discussions of wildland planning, the term has been applied loosely. There is no generally accepted statement of what it means or how it should be derived.

For purposes of this study, land tolerance is used as the principal measure of capability. Land capability is in turn defined as the level of use an area can tolerate without sustaining permanent damage through erosion and other causes. Although capability classes are expressed as levels of tolerance, they are estimated by the degree to which potential hazards arising from improper use are absent. (The lower erosion hazard a soil has, the higher its capability rating for development.) The classification is an interpretative grouping of kinds of land made primarily for the purposes of erosion control and maintaining ecological

balances. It should not be confused with the USDA agricultural capability system (Klingebiel and Montgomery 1961), which is designed to provide a relative rating of soils and management requirements of common field crops and is not generally applicable to forest lands.

Outline of Analysis Procedure

The procedure for establishing land capabilities involved a two-step system, as discussed in detail below, namely:

1. A hazard classification of land into homogeneous units for potential use consideration, and
2. An evaluation of the hazard classes on the basis of their ability to tolerate interference by man.

The first step divides and ranks the basin into seven levels of land capability according to the frequency and magnitude of hazards that are encountered, i.e., floods, landslides, high water tables, poorly drained soils, fragile flora and fauna, and easily erodible soils. Class 1 represents areas that exhibit the greatest frequency or highest magnitude of hazardous conditions, or both. Class 7 represents areas where the extent of hazardous conditions is negligible. In order to determine classes, a number of complex, interrelated influences were separately considered and evaluated (Tahoe Regional Planning Agency and USDA Forest Service 1971a-e). Data on soil type and land forms, which are major contributing factors, were separately compiled on maps at a scale of 2 inches to the mile. The maps were then evaluated and combined to define units representing particular combinations of both influences.

In the second phase of the system, the type and intensity of use suitable for each unit are considered, and the units are grouped into larger patterns so that recommendations can be made which will lead to policy decisions.

In the final evaluation, limits on land-surface modification for each unit are expressed as a percentage of each area that can be used for impervious cover.

FACTORS USED IN RATING CAPABILITY

Many highly interrelated factors determine hazardous situations. Particularly important to environmental quality are those affecting the hydrologic functioning of the land. (See Leopold 1968.) The principal factors used in distinguishing the seven ranks on the map are soil type and geomorphic setting.

Soil Type

It is widely recognized that the thickness, textural gradation, and chemistry of the soil determine the hydrologic processes that occur both on and below the surface of the soil. These in turn strongly influence patterns of erosion, runoff, and plant survival and growth. (See the review by Dyrness 1966, and studies by Anderson 1954, Anderson and Wallis 1965, and Pacific Southwest Inter-Agency Committee 1968.)

A total of 73 soil types (at the level corresponding to the soil series) have been identified and mapped in the Lake Tahoe basin by the Soil Conservation Service (Rogers 1972). Types differ in such properties as texture, depth, and slope. Interpretation of these differences, as mapped, provides an indication of where hazards and limitations exist. Differences of considerable value in characterizing soil types, and in making interpretations for various uses at a later stage, are those of erosion hazard, hydrologic-soil group, soil drainage, and rockiness and stoniness.

Erosion Hazard

The inherent or natural resistance of the surface soil to water erosion independent of vegetation and surface litter is termed *erosion hazard*. Sediment discharge from watersheds is significantly related to degree of resistance. Anderson (1954) has shown that differences in natural sediment production associated with differences in soil erodibility vary by a factor as high as 75 in upland areas of California. Where ground cover is depleted to less than the minimum density required to protect

the soil, sediment yields from relatively small areas may increase fantastically. The increase is proportional to the amount of soil laid bare and to the inherent erosion hazard of the soil.

The erodibility of a soil is a fixed property, and there is little possibility of changing it. Soils must be managed with this quality in mind, and the level of use adjusted accordingly. Soils with high erodibility must be left undisturbed or used with the greatest care.

Soils within the highly variable Tahoe basin differ greatly in their natural resistance to erosion. Erosion is proceeding so slowly in some areas that soil is being formed and accumulated more rapidly than it is being removed. Streams from such areas carry only negligible loads of sediment. In other areas, climatic and geologic conditions limit soil formation, plant growth, and fixing of land surface. From these drainages, runoff has always been rapid and erosion pronounced, giving rise to turbid and highly fluctuating streams. Between these extremes are areas showing all gradations of runoff and sedimentation rates.

Most of the inherent resistance or lack of resistance to erosion in basin soils appears to be related to two conditions. The first is the stability of the surface-soil aggregates. On natural slopes a lower proportion of soil particles and water-stable aggregates larger than 2 mm in diameter accounts for a significantly higher soil loss. The higher soil loss reflects an inherent difference between soil groups in the relative ease with which surface-soil particles and aggregates are detached and transported. The second condition is the ease with which surface horizons become saturated. If the body of soil is permeable and permits a reasonably rapid infiltration and downward percolation of water, the excess moisture passes through the soil rather than over it, eliminating potential erosion damage by surface flow. Any restriction or impedance to passage of water downward through the soil, such as an increase in clay content, textural discontinuities, hardpans, compacted layers, and shallow soil over impermeable layers or rock, increases erosion potential. Hussain et al. (1969) and Meeuwig (1971) have found coarse-textured soils on certain sites in the Lake Tahoe area to be water repellent in the presence of some organic matter. In these soils, rejected water runs over the ground surface, producing about 10 times as much sediment as similar but nonrepellent soils (Desert Research Institute 1969).

The effect of geology on soil erosion potential over most of the Tahoe basin is readily apparent. The volcanic outcrop areas, particularly the andesite, are among the most stable found in the basin. The soils derived from these rocks have sufficient silt- and clay-size fractions to provide the binding material that tends to hold the soil particles together and form aggregates. These aggregates offer resistance to raindrop impact and thus reduce sealing of the pores of the surface soil. Water reaching the soil surface is more likely to infiltrate than to flow over it. This infiltration characteristic and a deep soil profile allow practically all precipitation to percolate into the highly fractured and permeable bedrock. The prevailing characteristic of the more erodible soils is their tendency toward single-grained structure and uniform texture. Recent work in California by Wallis and Willen (1963) has demonstrated that soils derived from granodiorite, because of this tendency, are potentially 2.3 times more erodible than andesite. These soils are also shallow and are underlain by impermeable bedrock. As a result, even small amounts of water frequently cause erosion.

Disturbance resulting from land use accelerates soil loss. Watersheds with unstable soils, when disturbed by housing construction, logging, or intensive grazing, seem to be capable of producing 12 times the soil loss from undisturbed areas (Glancy 1971), whereas disturbance of the more stable soils causes variation by only a factor of two (State of California 1969).

Relative erosion hazard of Lake Tahoe basin soils has been established by the Soil Conservation Service (Rogers 1972), assuming that a protective cover of vegetation is not

present. It represents the combined effect on the soil of slope, climate, and soil erodibility. In this evaluation, erodibility is determined by detachability and transportability of soil particles and is influenced by soil structure, infiltration capacity, and permeability of the soil. Slope (length and shape) and climate are evaluated and integrated with soil erodibility to form inherent erosion hazard. A three-class scale of erosion hazard is used:

High. – Unprotected bare soil erodes sufficiently to damage severely and permanently the productive capacity of the soil or to yield excessively high volumes of sediment.

Moderate. – Soil is sufficiently resistant to erosion to permit limited and temporary exposure during development or use.

Slight. – No appreciable hazard of surface erosion is present when soil is bare.

The results of the survey for the Tahoe basin are summarized in *table 1*. The distribution of the three hazard groups of soils is shown in *figure 3*.

Hydrologic-Soil Group

An almost infinite number of conditions affect the infiltration of water into the soil and thus the amount of overland flow and sediment yield. Among these are texture of surface soil, inherent structure and consistence, depth of soil (especially to less permeable layers), porosity, and percolation rate of subsurface horizons. Collectively, these properties determine the receptivity of water into the topmost thin skin of the soil mantle.

Soils derived from different parent materials often vary in capacity to permit infiltration of precipitation. These differences may be inherent or induced. DeByle (1970), for example, found the average infiltration rate in coarse-textured soils derived from granite to be more than six times the rate measured in fine-textured soils derived from andesite. Erosion by water reduces infiltration by exposing less permeable horizons, and as the total infiltration capacity is diminished, by creating shallower profiles. The greatest post-erosion reduction in infiltration rates occurs in the fine-textured soils derived from andesite.

Infiltration rates in soils of any origin are readily reduced by land use. Removal of vegetation exposes soil to raindrop impact, which breaks up soil aggregates, leaving a compact, dense surface layer, through which water moves slowly. Loss of organic matter prevents the renewal of good soil structure, decreases protection of soil from the destructive action of raindrops, and increases the formation of soil frost. Compaction by trampling of animals or by machinery reduces infiltration. As infiltration decreases, there is a corresponding increase of overland flow and soil loss.

Surface erosion in sheet, rill, and gully form can only take place where overland flow occurs. Rain falling on a drainage basin encounters a variety of soils that determine a variety of hydrologic responses. There is in fact a continuum of surface conditions, ranging from areas with zero infiltration capacity and no soil cover, on which all runoff occurs as overland flow; through those with moder-

Table 1. – Lake Tahoe basin land area classified by inherent erosion hazard

Erosion hazard class	Area	
	Acres	*Percent*
Slight	61,880	30.6
Moderate	52,310	25.9
High	87,840	43.5
Total	202,030	100.00

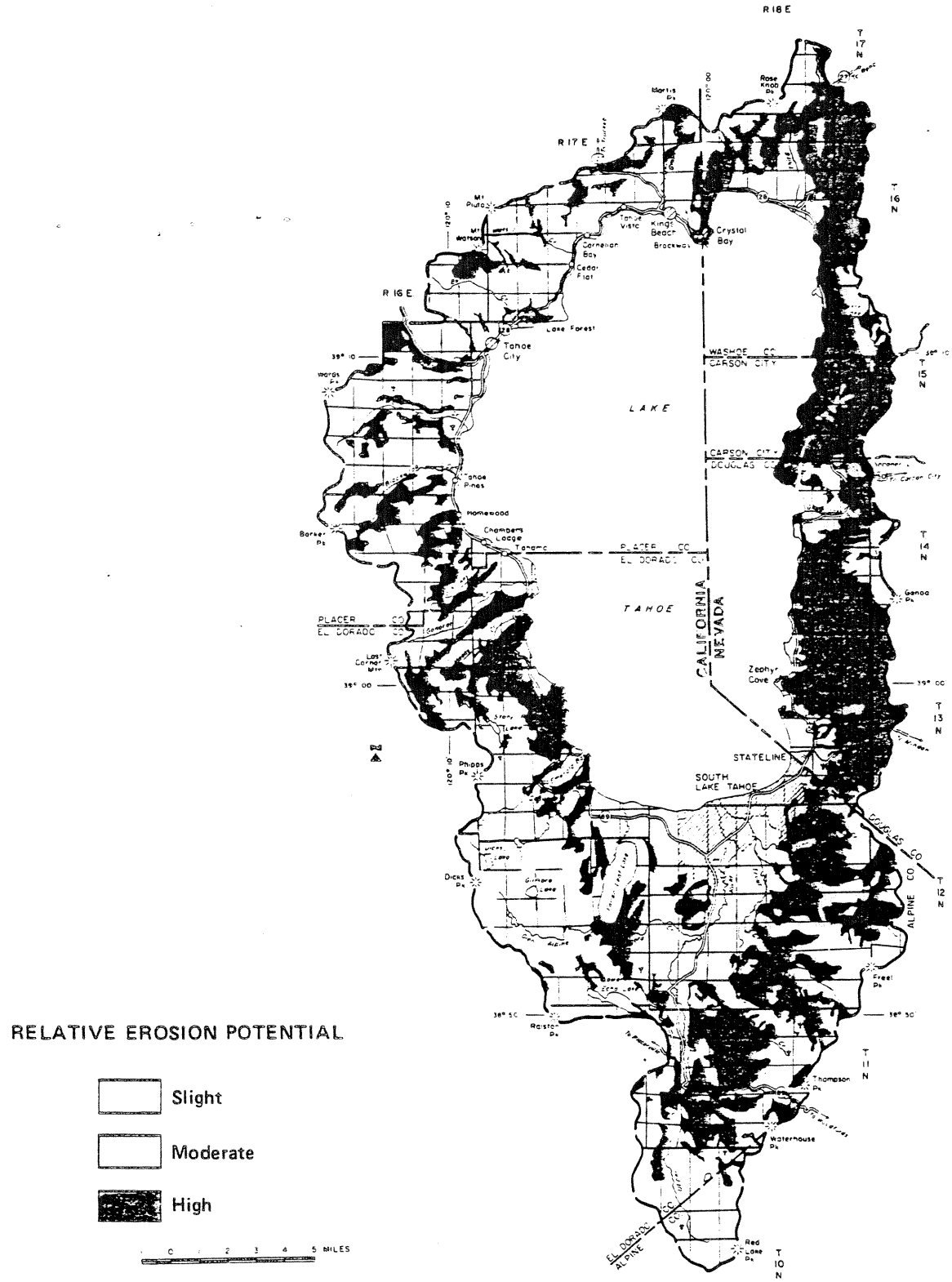

Figure 3. – Erosion hazard groups are related to land capability in this map of the Lake Tahoe basin. Relative erosion potential is shown by the pattern density; the darker the pattern, the more prone are the soils to erode and the less disturbance they can tolerate. (Kennedy and Rogers 1971, pocket)

ate infiltration capacities and thin soil, on which overland flow will occur at intervals of several months, years, or decades; to those with very high infiltration capacities and thick soil on which only throughflow or subsurface flow occurs. On most areas, most types of flow occur, although at markedly different frequencies. Variations in soil conditions influence the total water storage capacity of the soil and partly determine the zone of maximum runoff and hence the areas most likely to be eroded by running water. The zones most frequently saturated are those where lines of greatest slope converge, those adjacent to flowing streams, where local concavities occur, and those where the soil cover is locally thin or less permeable (Kirkby and Chorley 1967). The effectiveness of these differences in defining rates of soil erosion from varying runoff source areas has been demonstrated by Doty and Carter (1965).

Classification of soils in the Tahoe basin into hydrologic-soil groups (Rogers 1972) yields estimates of soil water storage, an important element in control of runoff and erosion patterns. A given hydrologic-soil group, when thoroughly wetted, has a minimum rate of intake that is reasonably constant and reproducible for that soil group. (The influence of vegetative ground cover is treated independently and is not considered in making hydrologic groupings.)

The broad array of hydrologic-soil groups is divided into four infiltration groups according to runoff potential:

Group A. – Soils having high infiltration rates (greater than 0.30 inch per hour), even when thoroughly wetted, and consisting chiefly of deep, well-drained to excessively well-drained coarse-textured soils. These soils have a high rate of water transmission and have *low runoff potential.*

Group B. – Soils having moderate infiltration rates (0.15 to 0.30 inch per hour), even when thoroughly wetted, and consisting chiefly of moderately deep and deep, moderately well-drained and well-drained soils with moderately fine and moderately coarse textures. Soil permeabilities are moderately slow to moderately rapid. These soils have a moderate rate of water transmission and have *moderately low runoff potential.*

Group C. – Soils having slow infiltration rates (0.05 to 0.15 inches per hour) when thoroughly wetted, and consisting chiefly of well-drained and moderately well-drained soils with slowly permeable and very slowly permeable layers (fragipans, hardpans, hard bedrock, and the like) at depths of 20 to 40 inches. These soils have a slow rate of water transmission and have *moderately high runoff potential.*

Group D. – Soils having very slow infiltration rates (less than 0.05 inches per hour) when thoroughly wetted, and consisting chiefly of shallow soils over nearly impervious materials, or soils with high permanent water tables. These soils have a very slow rate of water transmission and have *high runoff potential.*

The results of this classification are summarized in *table 2.* The distribution of the four groups is shown in *figure 4.*

Table 2. – Lake Tahoe basin lands classified by hydrologic-soil group

Hydrologic-soil group	Area	
	Acres	*Percent*
A Low runoff potential	9,710	4.8
B Moderately low potential	46,470	23.0
C Moderately high potential	80,425	39.8
D High potential	65,425	32.4
Total	202,030	100.0

Soil Drainage

Among sources of sediment, the possible yield from channel erosion must be considered. Many streams descending from the mountain ranges in the Tahoe basin have ag-

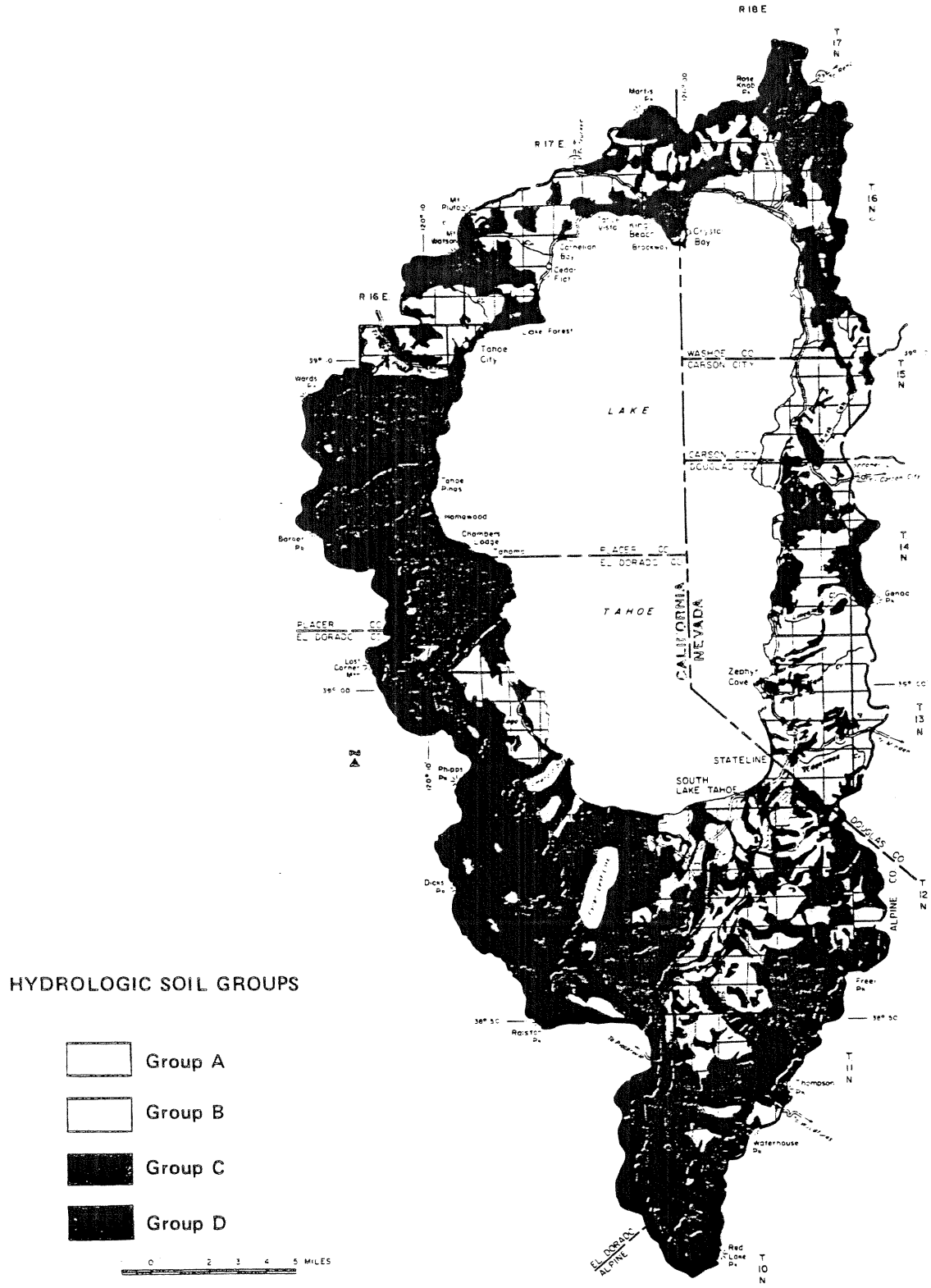

Figure 4. – Hydrologic-soil groups are related to land capability in this Lake Tahoe basin map. Relative runoff potential is shown by the density of the pattern; the darker the pattern, the less the ability of the soil to absorb water, and hence the more restrictive to development. (Kennedy and Rogers 1971, pocket)

graded their lower reaches and have built alluvial fans flanking the ranges. The bulk of these alluvial deposits is doubtless a mixture of glacial outwash, lake deposits, and material derived from accelerated fluvial erosion and loss of stream volume accompanying postglacial changes in climate. Stream channels flowing over these deposits meander widely. Deposition of sediment load in the channel forces an alteration of course almost every year.

Because these areas are surrounded by steep slopes and shallow soils, with high runoff characteristics, a common natural process is flooding and redeposition of alluvial material carried downvalley from upland slopes. Hill slope debris and runoff from adjacent slopes generally must pass through the valley flat before reaching the channel. These areas not only protect the channel from flashy runoff and erosion, but also intercept and store much of the floodwater and sediment that would otherwise contribute to downstream floods and sedimentation.

Alluvial soils developed along the major streams and meadow bottoms in these areas are deep, friable, and low in inherent erosion hazard. They have poor drainage and high water tables, and are in general highly organic. Water retained within the alluvium promotes a luxurious growth of vegetation, which aids in the development of a flood plain, stabilizing banks and acting to dissipate the energy of flood waters moving across the plain.

Removal of alluvial debris produced by channel erosion accounts for a significant part of the total sediment load carried by streams in the Tahoe basin. For example, its contribution has been estimated as 39 percent of the total sediment available for transport in Trout Creek and the Upper Truckee River (State of California 1969). This relationship has practical importance because disturbance resulting from land use may accelerate the removal process, thus increasing the delivery ratio. For example, channel erosion from logging in the Castle Creek basin near Donner Summit produced average sediment concentration of about eight times that expected from the prelogging relationship (Rice and Wallis 1962). Furthermore, much of this alluvium is yet to be removed and large quantities of potential sediment are temporarily stored immediately adjacent to stream channels – awaiting streamflow peaks high enough to carry it to the lake. As this material is high in organic content, it is a source of nutrient enrichment to the lake, with detrimental effect on the water quality.

Generally speaking, land uses that reduce natural storage capacity aggravate the flooding problem. Such flooding not only damages land and buildings bordering the stream, but also widens and deepens the channel and utterly disrupts the stream environment. Buildings in the flood plain are dangerous for the inhabitants; they also impede the flow of flood water by constricting the channel, thus increasing velocities downstream. Obstructions change the streamflow regime and often cause the stream to seek a new channel, a process that includes bank cutting and channel reworking, with consequent sedimentation and loss of aquatic habitat. Channel straightening and relocation have similar results.

New drainageways provided by uncontrolled road drainage, with gullying to the nearest natural channel, are always a major source of sediment. As the gullies work headward in the unconsolidated alluvium, they can cut to depths of 75 to 100 feet, lowering the ground water table and thus adversely affecting stabilizing vegetation.

Accumulations of natural and man-caused debris can be very destructive to downstream areas during periods of high streamflow. Following heavy rains or snowmelt, such flow can bring the debris into suspension, transmitting it downstream until an obstruction is encountered. The debris jams that form behind these obstructions result in bank erosion as water is forced around the plugged channel. Subsequent material from upstream erosion accumulates behind this temporary barricade, and storm runoff water is held back by it. When the dam gives way, a flood surge highly

charged with debris is released down the channel with great destructive effect.

Removal of vegetation along streams by intensive grazing and trailing by livestock, or by logging, allows more rapid water flow, thereby increasing erosion potential. In addition, by greatly increasing the surface area exposed to solar radiation, the removal of the vegetation canopy along streams can increase the water temperature and alter the biotic community of the stream. As water temperature increases, the physical capacity of water to hold oxygen decreases. At the same time, decomposition of organic debris tends to increase oxygen consumption. Under such conditions, competition for oxygen in the aquatic community may become strong. Shapley and Bishop (1965) reported a study of the effect of temperature on fish production in small north coast streams in California. In one reach, only 578 feet in length, water temperature increased from 60°F to 75°F because of exposure to the sun. Stream sections well exposed to the sun contained dense growth of algae, whereas the well-shaded sections did not. Fingerling salmonoids appeared to be considerably less abundant in stream sections where algae growths were extensive. Similar results have been reported by Brown and Krygier (1967) for small mountain streams in Oregon's Cascade Range, and by Cordone and Kelley (1961) in California.

Surface watercourses and adjacent poorly drained alluvial soils are points of interchange between surface water and ground water systems. Such interchanges are highly important to hydrologic relationships. The discharge of ground water to the surface contributes water to streams in periods of low flow. At the interchange, also, polluted streams may contaminate the relatively clean – and frequently pure – water resources in shallow aquifers. In addition, interchange points may be prime recharge areas to existing or potential ground-water supplies. If these areas are paved or otherwise covered, much of their recharge potential may be lost. During summer or periods without rain, sustained flow from ground water provides more water to dilute materials occurring naturally in the surface water or introduced into it. The failure of an urbanized drainage basin to sustain its flow would mean a greater concentration of pollutants at those times. Points of interchange should therefore be considered critical for the management and protection of ground-water resources.

Overloading of natural channels by rapid runoff and sediment from urbanized areas will inevitably start a cycle of bank cutting, meandering, and reworking of old deposits that will adversely affect both water quality and aquatic habitat. Such upsets are particularly harmful because these areas are usually the zones of prime wildlife habitat and fish spawning grounds. Generally, when development is located far from streams, some of the runoff from impervious surfaces can be absorbed by the ground enroute to the stream. Natural cover maintained on poorly drained soils adjacent to streams aids in the infiltration of precipitation and surface runoff, filters out sediment and pollutants, and provides shade for stream water.

Poorly drained lands constitute about 5 percent of the Tahoe basin area (*fig. 5*).

Rockiness and Stoniness

In some areas, floods and high rates of erosion are natural. They are common in the subalpine and alpine zone because of a combination of sparse vegetation and shallow soil or impervious bedrock. Here rock outcrops and stones make up 50 to 90 percent of the surface area. Snow melts faster in these rocky and stony lands in the absence of forest cover. Without a soil and plant mantle to dispose of rainfall and snowmelt water, stream discharges have been intermittent, violent, and often laden with debris. In the basin, in watersheds with a high percentage of exposed rock, up to 70 percent of the total precipitation ends as runoff (Crippen and Pavelka 1970).

Vegetation minimizes downstream flooding and siltation. Mud-rock flows occur during

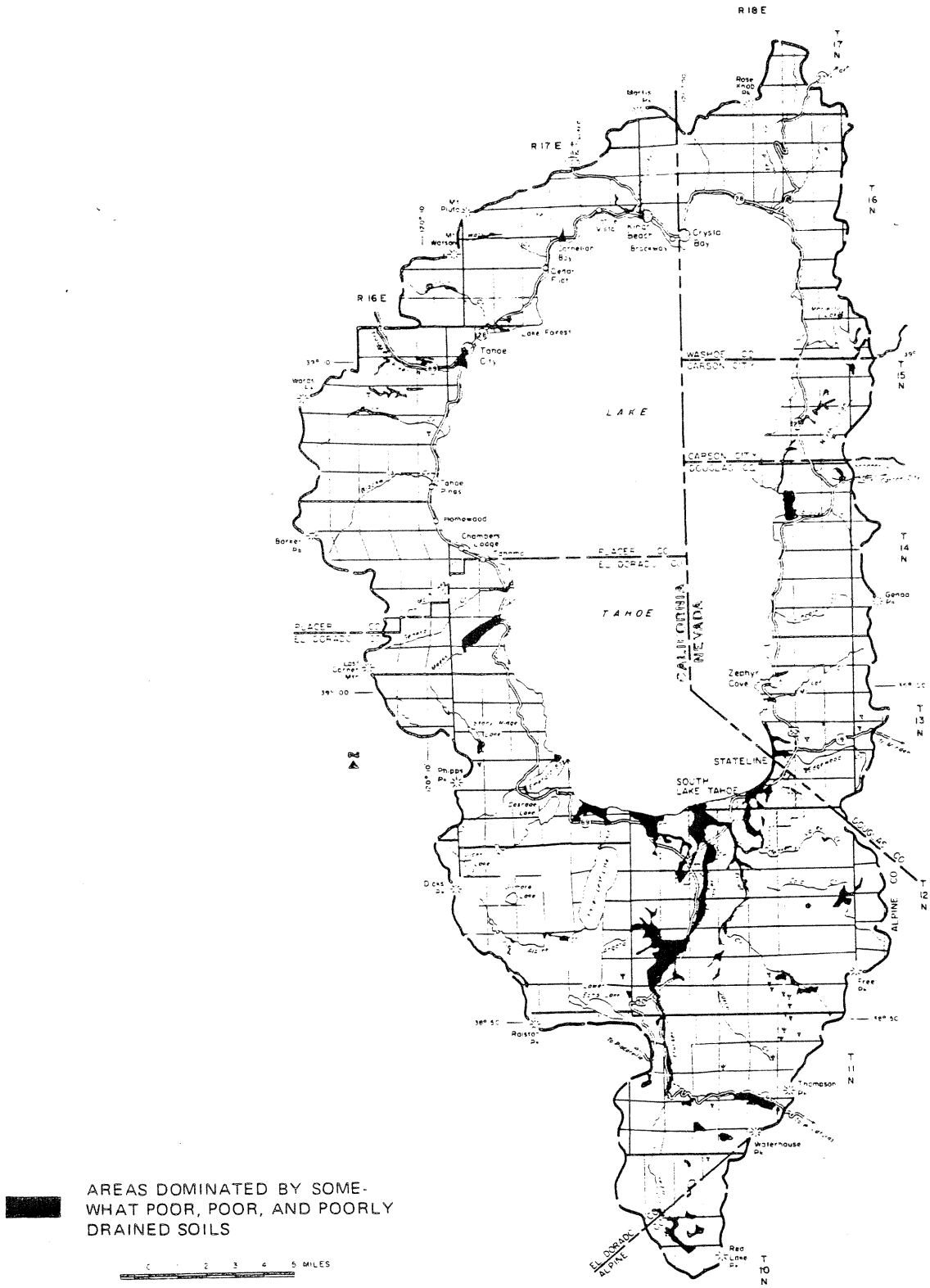

Figure 5. – Soil drainage is related to land capability in the Lake Tahoe basin in this map. Areas that are undevelopable because of flooding and high water tables are indicated. (Kennedy and Rogers 1971, pocket)

periods of torrential summer rains where the natural plant cover has been altered by grazing (Glancy 1969). In the high mountains or subalpine forest near timberline, fire damage to these flood source areas has been more severe than in any other area in the basin. Here the thin soils and the harsh climate have all too often made single fires as devastating as repeated burns lower down. It may take centuries for a new forest and good humus to develop. Even where soil-plant relations are fragile, however, watershed management can reduce flood peaks and sediment loads to the extent that they have been increased by impairment of the plant cover.

Exposed rock at lower elevations is reported to cause soil erosion. Haupt (1967) found that on rocky bare plots, soil movement exceeded that under all other forest floor conditions. Overland flow erodes and transports detached soil; exposed rock apparently accelerates the process by concentrating the flow in surface openings between rocks. Thus, as surface flows are increasingly confined by impervious cover, soil losses increase.

Land of the exposed rock type makes up about 28 percent of the Tahoe basin area (*fig. 6.*).

Geomorphic Setting

The complex of soil properties in an area is basic consideration in assessment of land capability. Geomorphic processes – those which shape the relief features of the earth – modify soil behavior, however. Locally these processes can be even more influential than inherent soil properties. The interrelation of all the environmental influences creates a continuity unique to a given geomorphic unit. Recognition of this continuity allows prediction of soil behavior throughout the unit.

The geomorphic continuity in a unit may be expressed in the morphologic pattern of the landscape. The slopes may weather and erode in a predictable manner, and the slope angles may lie within a definite range, all leading to a general homogeneity in the landforms. Appreciation of this morphologic pattern in a given unit is useful in analyzing land capability and in differentiating between kinds of erosion. (See Brown et al. 1971, Christian and Stewart 1968, Hills 1966, Retzer 1965, Spilsbury et al. 1965, and Wertz and Arnold 1972.)

The geomorphology of the Lake Tahoe basin has been described by Bailey (1971b), and only the highlights will be mentioned here. Geomorphic units were delineated on the following basis:

- Minimum size: 1 square mile
- Broad similarity in type of landform development (relief and drainage patterns, slope, texture of dissection, etc.)
- Distinctive internal structure of the landform and surface material
- Distinctive pattern of land and water areas (as in a complex glaciated landscape with many lakes and other water bodies)

In all, 15 geomorphic units were recognized (*table 3*). Geomorphic units occur within six major groups: glaciated granitic uplands, glaciated volcanic flowlands, streamcut granitic mountain slopes, streamcut volcanic flowlands, depositional lands, and oversteepened slopes. These are briefly discussed below.

A. Glaciated Granitic Uplands

These lands lie along the Sierran crest, extending from the upper Truckee River canyon to Ellis Peak. They consist of mountainous uplands, glacial basins, and troughs that have been scoured by repeated glaciation. Rock outcrops, rubble, and very shallow soil dominate these areas. Vegetation is sparse; most of the area is barren. These conditions, in combination with harsh climate, place severe stresses on plant and animal systems. The vegetation is fragile, and once destroyed by fire or overuse, it may take centuries to regrow. With a meager soil and plant cover to dispose of rainfall and snowmelt, stream discharges are often violent and are a major

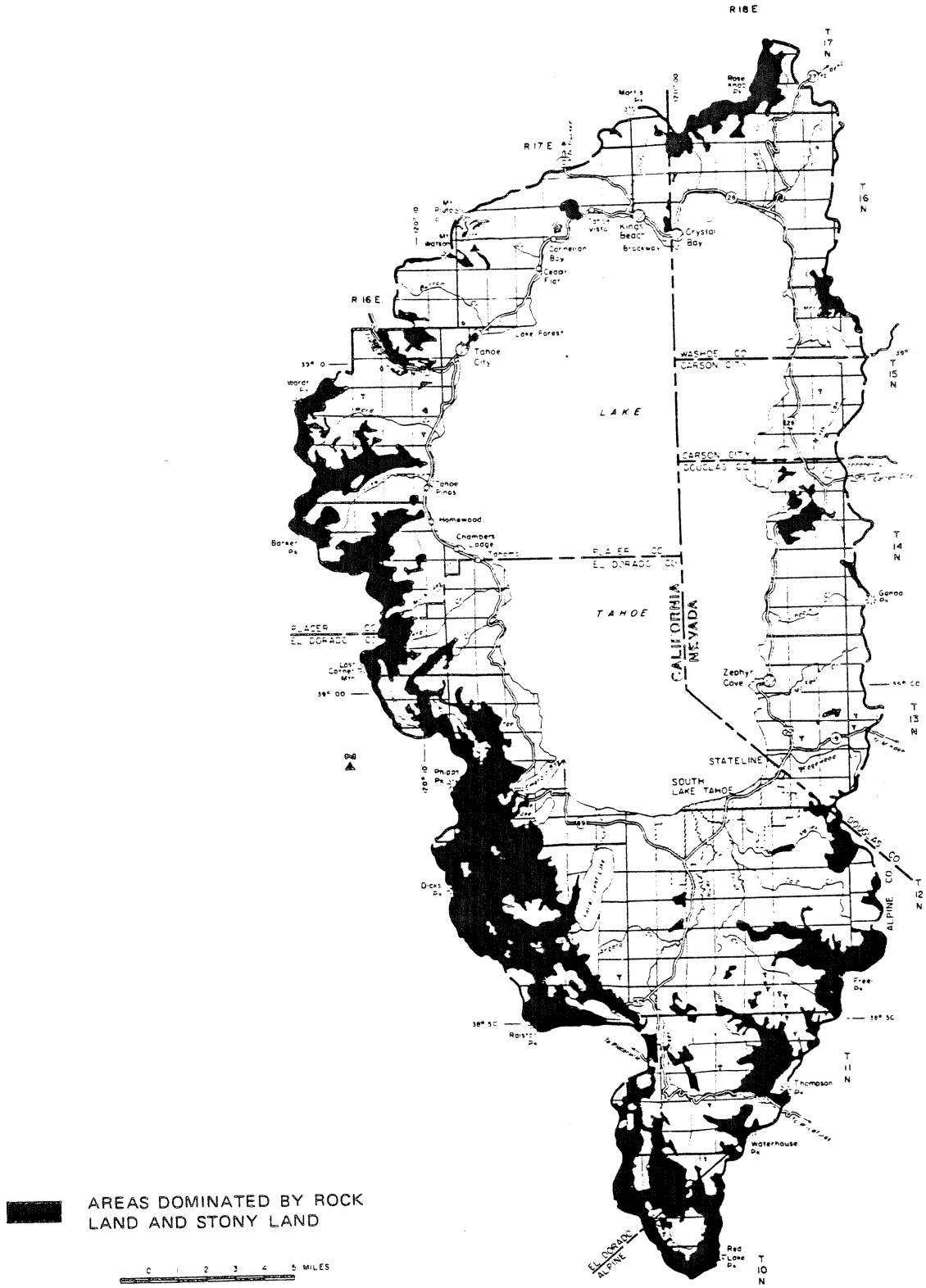

Figure 6. – Rockiness and stoniness are related to land capability in this map of the Lake Tahoe basin. Areas that are undevelopable because of high runoff and fragile flora and fauna are indicated. (Kennedy and Rogers 1971, pocket)

Table 3.—Geomorphic units, Lake Tahoe basin

- A. Glaciated granitic uplands
- B. Glaciated volcanic flowlands
  - B_1 Glaciated volcanic flowlands undifferentiated
  - B_2 Rocky ridge lands
- C. Streamcut granitic mountain slopes
  - C_1 Granitic foothills
  - C_2 Strongly dissected lands
  - C_3 Steep strongly dissected lands
  - C_4 Moderately dissected weakly glaciated lands
  - C_5 Subalpine rim lands
- D. Streamcut volcanic flowlands
  - D_1 Toe slope lands
  - D_2 Headlands
- E. Depositional lands
  - E_1 Moraine land undifferentiated
  - E_2 Outwash, till, and lake deposits
  - E_3 Alluvial lands
- F. Oversteepened slopes
  - F_1 Canyon lands
  - F_2 Escarpment lands

source of flood runoff in the basin. The bedrock is mainly hard, massive granite. Because of recent glaciation, weathering has not acted long enough to decompose these rocks into fine material that can be eroded by running water. Cloudburst floods transport coarse material in valley bottoms, however, and frequently produce mudflows with entrained coarse debris that reach canyon mouths.

B. Glaciated Volcanic Flowlands

These lands lie along the Sierran crest, extending from Ellis Peak to the Truckee River outlet. Though shaped by glaciation, the topography is more subdued here than in unit A because the volcanic bedrock is not as strong as the massive granite. Topography varies from steep volcanic ridge lands, with large glacial basins at the heads of major drainages, to gentle slopes in valley bottoms. Glacial debris is plastered on valleyside slopes and contains sufficient fine-grained material to store water for dense timber growth. Rock outcrops appear on the ridgelands and on basin walls, and supply high amounts of runoff to lower-elevation timbered areas, which absorb and store it. Disruption of this subsurface flow by road and stream cutting is a frequent source of slope instability and erosion in this type of unit.

C. Streamcut Granitic Mountain Slopes

These lands lie along the Carson Range and are the primary source of potential erosion in the basin. Stream erosion, rather than glaciation, has dissected the area into an intricate arrangement of V-shaped canyons with numerous intermittent drainage channels. Steep slopes contribute to high erosion potential. The deep dissection places any location on a slope only a short distance from a stream channel, and large quantities of sediment are rapidly delivered to the lake because there is little opportunity for the sediment to be trapped along the way. The bedrock is massive granite overlain by grus or decomposed granite. Soils are shallow and are underlain by almost impermeable bedrock. Being coarse in texture and poorly bonded, soils are easily eroded. The low water-holding capacity and natural infertility of the soil, with a short, dry growing season, make revegetation extremely difficult. Glaciated granite, by contrast, does not share these rock weathering and drainage characteristics and presents a completely different environmental management problem.

Urbanization, repeated logging, overgrazing, and fires have damaged the natural ground cover. As a consequence, many areas have sparse vegetation and exposed soil and rock. As noted earlier, in soils on some sites, water repellency results in high erosion rates. Instead of producing gullies, however, the surface soil materials often slide or run when dry and quickly erase evidence of surface erosion.

Decomposed granitic rock in roadcuts often disintegrates within 1 or 2 years after construction. This process supplies sediment to the interior road ditch where it can be picked up by storm runoff and transported to a culvert inlet and thence to a stream channel.

On the more weathered bedrock areas, this form of erosion is estimated to progress at the phenomenal rate of 1 inch per year.

Water concentrated from impervious surfaces, such as paved roads, produces severe gully and channel erosion in loose decomposed granitic material. Fills for roads and parking lots constructed with this material are frequently washed out when drainage is inadequate or improperly installed. This debris is periodically flushed from the channel during storm or snowmelt runoff and transported to the lake.

D. Streamcut Volcanic Flowlands

These lands lie across the northwest sides of the basin and consist of gentle mountain slopes and partially opened valleys. Although stream erosion has shaped this unit, drainage channels are few. Deep, fine-textured soils support an evenly distributed forest cover. In contrast to soils of other units in the basin, these soils have the highest natural fertility and lowest erosion hazard, because the underlying volcanic rock is highly fractured and permeable, making surface runoff minimal. Also, a large part of the runoff moves to the stream channels as subsurface flow within the deep volcanic soils. Interception of the flow, by road cutting for example, concentrates water and can cause erosion. Because of their fine textures, some soils tend to be easily deformed. Thus, under the right combination of moisture and slope, they may slide or slump. This is especially true where the slope is oversteepened for construction purposes.

E. Depositional Lands

These lands occur along valley bottoms and are widespread around the margin of the lake. The geology varies from bouldery glacial debris to coarse sandy outwash and recent fine-grained alluvium along stream channels and meadow bottoms. Also included are lake deposits of variable composition. Soils developed along the major streams and meadow bottoms are deep and low in inherent erosion hazard. They have poor drainage, however, and other characteristics described earlier as typical of the poorly drained alluvial soils (see p. 9). Glacial deposits on steep slopes have thinner soils with a high erosion potential and are subject to landsliding when undercut.

F. Oversteepened Slopes

These lands, extending from Echo Summit to Emerald Bay and including the Truckee River canyon, are characterized by steep cliffs formed by faulting and narrow canyons. Slopes are very steep; some are vertical. Most of the unit is dominated by rock outcrops, debris, and rubble. Rockfalls and avalanches of snow and rock occur more frequently in this unit than in any other in the basin. Landsliding of rock and soil is accelerated when such delicately balanced slopes are disturbed by the works of man. The Emerald Bay slide of 1953 was triggered by undercutting of an already unstable slope for road construction.

Hazard Rating of Geomorphic Units

Each one of the geomorphic units recognized above has a distinctive capability for use or development. A ranking of the units in three groups according to hazard potential was determined through careful examination of such characteristics as depth to the water table, soil texture, soil-plant relationships, depth to bedrock, and potential for floods and landslides. The ranking is determined by the degree of hazard (relative to other hazards found on all units); the percentage and pattern of the hazardous land within a unit; and the versatility of the land – its ability to sustain a multitude of activities without conflict.

Group I. High hazard lands. – On a Group I geomorphic unit, one or more of the abovementioned potentially hazardous situations exist. The land characteristics of particular geomorphic units in this group are fairly uniform in having the same potential hazard over much of their area. Therefore, in planning, it is more difficult here than elsewhere to avoid hazardous situations by proper location of a conflicting activity.

These lands are not hazardous for all activities, but are limiting for more activities than Group II or Group III lands. They limit most

strictly those activities which disturb the soils. Group I consists of:

- A Glaciated granitic uplands
- B_1 Glaciated volcanic flowlands undifferentiated
- B_2 Rocky ridge lands
- C_2 Strongly dissected lands
- C_3 Steep strongly dissected lands
- C_4 Moderately dissected weakly glaciated lands
- C_5 Subalpine rim lands
- E_3 Alluvial lands
- F_1 Canyon lands
- F_2 Escarpment lands

This group includes about 61 percent of the Tahoe basin area.

Group II. Moderate hazard lands. – Group II geomorphic units also have hazardous characteristics, but differ from Group I lands in that these characteristics are not uniformly distributed over the area. Hazardous areas are a smaller percentage of these lands and tend to be obvious and scattered so that there is a good chance of avoiding them through careful location of land-disturbing activities. There is a better opportunity for a wider variety of activities on Group II lands than on the Group I lands because of the lower percentage of hazardous areas. High impact activities such as road construction, which are most disturbing to the landscape, can be designed to occupy the more stable portions of these lands. Group II consists of:

- C_1 Granitic foothills
- D_2 Headlands
- E_1 Moraine land undifferentiated

This group includes about 25 percent of the Tahoe basin area.

Group III. Low hazard lands. – Group III is the least fragile of the geomorphic units. Because hazardous areas are few, there is a better chance to avoid them. These lands can support the widest range of activities, but care must be taken to avoid abuse. Even on these lands, project sites need to be checked for hazards through a detailed site evaluation. Group III consists of:

- D_1 Toe slope lands
- E_2 Outwash, till, and lake deposits

This group includes about 14 percent of the Tahoe basin area.

The distribution of the three groups of geomorphic units described above is shown in *figure 7.*

COMBINED CAPABILITY RATING

In the preceding sections the evaluation of factors affecting hazard are shown on a series of maps (*figs. 3, 4, 5, 6, and 7.*). Each map indicates areas or localities where natural features or processes indicate varying degree of hazard based on either soil or geomorphic conditions. No absolute evaluation of hazard was attempted; only relative hazard within the area was considered. The land capabilities map (pocket) combines the data presented on each of the other maps to provide a single hazard rating of the basin.

The first step in establishing the combined rating was to group the geomorphic units into two general use categories: usable and unusable. Unusable units of uniform and widespread instability, as shown by the prevalence of hazardous conditions (i.e., high hazard lands), were designated directly as class 1.

Lands in the remaining units (where hazardous conditions are variable or otherwise not of overriding significance) were assigned to a range of capability classes from 1 to 7 based on combined soil characteristics shown in *table 4.* The most restrictive class (class 1) is divided into subclasses according to kind of limitation. For a list showing the capability level to which each soil type is assigned, see the Appendix.

The land area in the various capability levels is given in *table 5,* and some of these lands are shown in *figure 8.*

RECOMMENDED USE

The evaluation of the hazard factors allows establishment of classes of varying degrees of

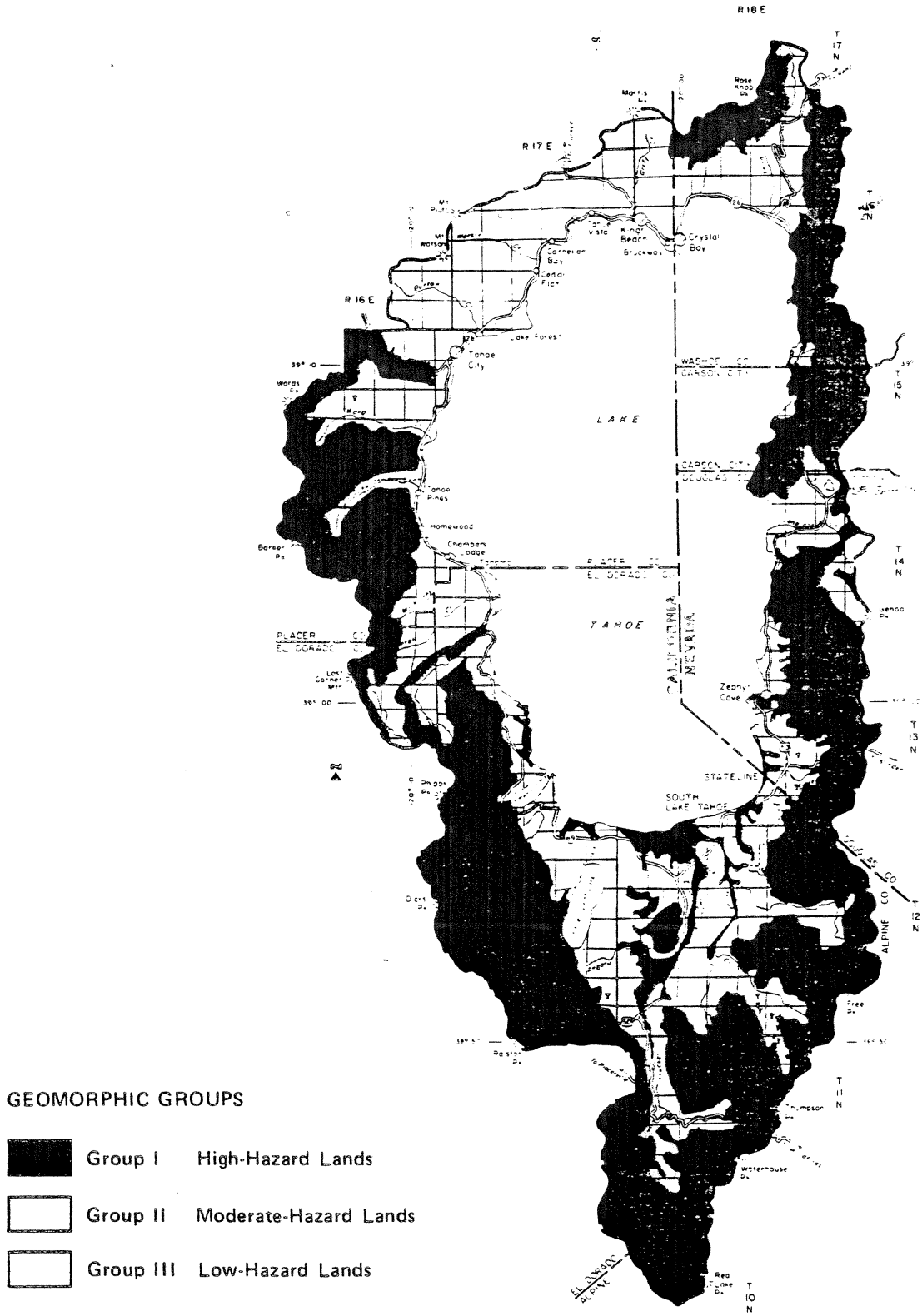

Figure 7. – Geomorphic groups are related to land capability in the Lake Tahoe basin in this map. Areas where natural features or processes pose varying degrees of hazard based on either geologic, soil, or geomorphic conditions are indicated. Darkest pattern shows land most restrictive to use and development.

Table 4. – Basis of capability classification for Lake Tahoe basin lands

Capability levels	Tolerance for use	Slope percent[1]	Relative erosion potential	Runoff potential[2]	Disturbance hazards
7	Most	0-5	Slight	Low to moderately low	
6		0-16	Slight	Low to moderately low	Low hazard
5		0-16	Slight	Moderately high to high	
4		9-30	Moderate	Low to moderately low	Moderate hazard lands
3		9-30	Moderate	Moderately high to high	
2		30-50	High	Low to moderately low	
1a	Least	30+	High	Moderately high to high	High hazard lands
1b		Poor natural drainage			
1c		Fragile flora & fauna[3]			

[1] *Most slopes occur within this range. There may be, however, small areas that fall outside the range given.*

[2] *Low to moderately low – hydrologic-soil groups A and B; moderately high to high – hydrologic-soil groups C and D.*

[3] *Areas dominated by rocky and stony land.*

Table 5. – Lake Tahoe basin land area classified by capability

Land capability class	Total area		National Forest land	
	Acres	*Percent*	*Acres*	*Percent*
7	3,030	2	101	1
6	8,800	4	1,144	1
5	16,730	8	4,878	4
4	7,050	4	1,421	1
3	12,900	6	3,471	3
2	4,770	2	2,012	2
1	148,750	74	102,266	88
Total	202,030	100	115,594	100

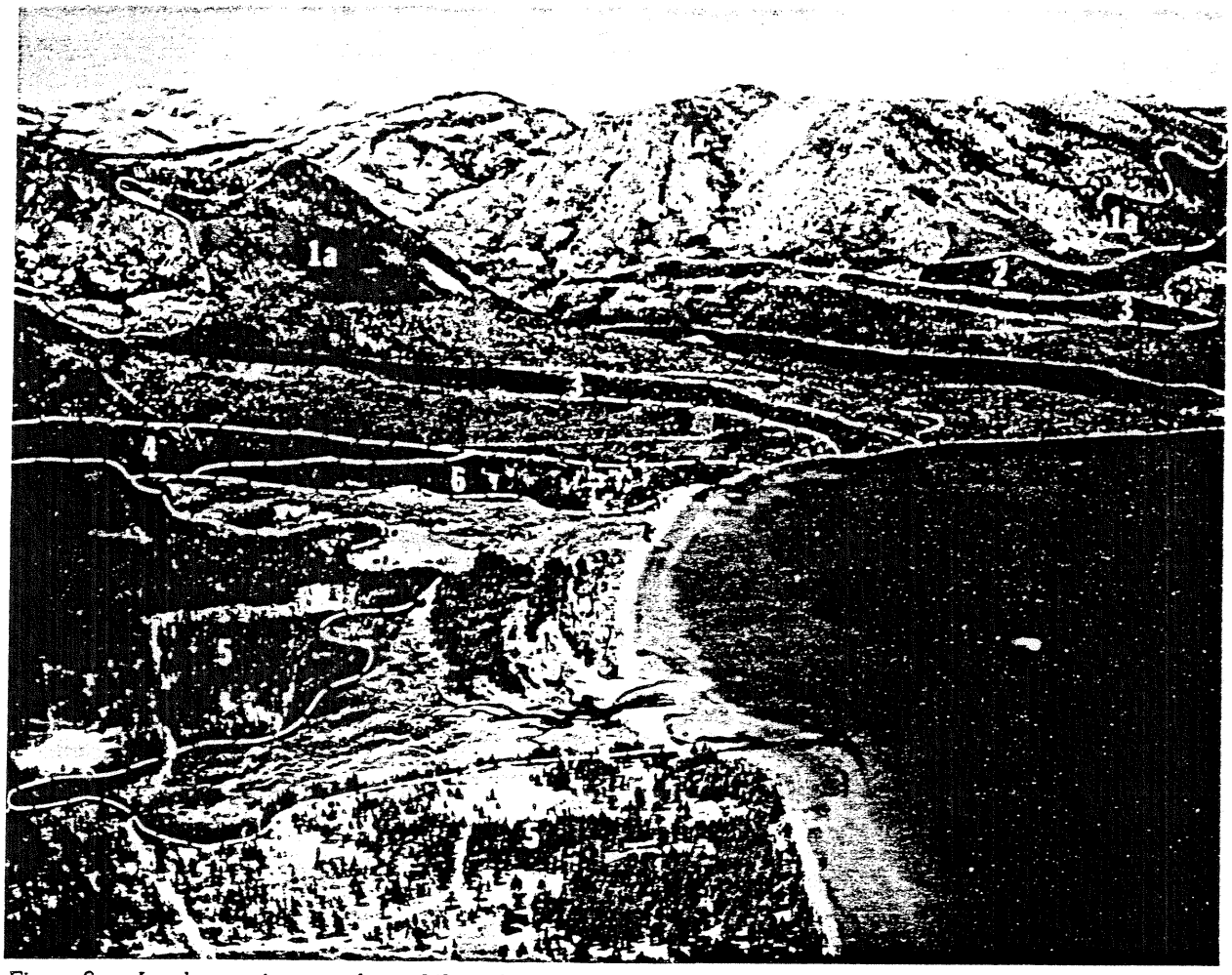

Figure 8. – Land areas in several capability classes may be found around the south shore of Lake Tahoe. (R. G. Barton Aerial Photography, annotation by writer.)

tolerance to land development. The potential impact of land use and therefore the required protection – is a function of both the tolerance of an area and the characteristics of the proposed development. Thus, the type and intensity of use and management that are suitable for land in each of the capability classes can theoretically be determined by combining the index values for land tolerance and development stress. Using this approach, the implications of the seven hazard classes were considered in relation to a broad range of prospective land uses. The following guides to use and management are **recommended** for each capability class. These guides must, of course, be adapted to the socioeconomic conditions and the objectives for the planning area.

The range in the seven classes extends from land capable of tolerating a high degree of interference without permanent damage to water quality or land productivity (class 7) to land that should remain in its natural condition but may be suitable for wildlife, dispersed recreation, or protection of watersheds (class 1). The seven capability classes are further grouped into three broad categories according to the relative risk of land damage (disturbance hazard).

High hazard lands (class 1 and 2) are characterized by steep slopes and a fragile environmental balance, with unique plants and animals. They also have scenic value as backdrops and foregrounds for surrounding areas. These should remain generally in their natural condition. To be suitable, uses of these lands should allow for protection and improvement

of visual, wildlife, and watershed values. Access facilities should be restricted generally to foot and horse trails. Recreational use will need to be dispersed and generally limited to hiking, backcountry camping, and fishing. These lands should not be managed for intensive commercial resource use.

Moderate hazard lands (class 3 and 4), characterized by moderately steep mountain slopes, will allow certain uses but not others. Often they provide visual backdrops for low hazard areas. Access should be by low standard roads and trails. Recreation use may be varied and concentrated, including campgrounds, picnic areas, and winter sports sites. Low-density housing may be permitted on occasion, as well as limited harvest of forest products.

Low hazard lands (class 5 thru 7) are areas of gently sloping foothills and plains with deep soils. They are generally suitable for various development activities as well as for concentrated public occupancy. Access should be by high-standard roads and trails. This land may support most kinds of intensive or mass recreational use if developed judiciously. Usual facilities include campgrounds, organizational camp sites, recreational residences, hotels, and resort or other commercial services. Limited commercial resource use is appropriate where it does not tend to destroy other values.

A general summary of the conditions associated with each land capability class will clarify their implications for land use. For the land area in each class, see *table 5* above.

Lands That Should Remain In Their Natural Condition

Land capability classes 1 and 2 are not suited for urbanization or intensive forestry use, but are suited for open space, conservation areas, and low-intensity recreation. The range in capability from 1 to 2 indicates increasing tolerance for use. About 76 percent of the basin (153,520 acres) is included in this category.

Class 1 land (gray on pocket map) is not suited for development, grazing, or forestry use. It has value for wildlife, recreation, or protection of water supplies. This land class includes mountaintops with little or no soil mantle; very steep mountain slopes with shallow soils; and marshes, flood plains, meadows, and beaches. The different kinds of class 1 land are shown on the map by subclasses.

Subclass 1a land consists of extensive areas of steep mountainous land with very shallow soils (*fig. 9*). These areas are the principal sources of sediment that cause damage to streams, water storage facilities, and structures. Erosion control and diminution of the velocity of runoff are the problems here. A maximum growth of vegetation should be

Figure 9. – Subclass 1a land severly affected by erosion is evident near Heavenly Valley. Vegetation is sparse and some areas are bare.

Figure 10. – Typical subclass 1b meadow land is found in the upper Truckee River valley.

established and maintained on these areas for soil stabilization.

Subclass 1b is a narrow one including stream channels, marshes, flood plains, and meadows (*fig. 10*). These lands are naturally wet and poorly drained and are critical areas for management and protection of water resources. Policy for use of these lands should reflect their value as floodwater and sediment storage areas, wildlife habitat, and fish spawning grounds.

Subclass 1c consists of extensive areas of mountainous uplands having little or no soil mantle (*fig. 11*). It includes the recently glaciated crests of the Sierras and other rocky areas with very shallow soils. Here the harsh climate and lack of soil severely limit plant growth and wildlife. Biotic communities exist in a delicate natural balance. The present vegetative cover should be protected from fire and undue disturbance. The chief value of this land is for watershed protection, wildlife habitat, and recreation.

Class 2 land (dark green on map) is suited only for limited recreation, restricted grazing, and selective timber harvest because of erosion hazard or very steep slopes. Because the slope of the land is more than 30 percent, careful grazing and logging practices are necessary to avoid loss of soil by water erosion. This type of land is limited in extent and lies in scattered areas at the base of steep mountain slopes and along entrenched stream valleys.

Lands That Are Permissive to Certain Uses But Not Others

Land capability classes 3 and 4 are not suited for urbanization but are suited for forestry and low-density housing use. The range in capability from 4 to 3 indicates increasing need for care and protection even in forestry and housing use. About 10 percent of the basin (19,950 acres) is included in this category.

Class 3 land (light green on map) is fairly well suited for forestry and low-density housing. The slope of this land varies from 9 to 30 percent and has moderate erosion hazard. Development here must be carefully designed and carried out to keep the land permanently productive. These lands consist of limited areas of moderately steep mountain slopes scattered throughout the basin at lower elevations.

Class 4 land (yellow-green on map) is well suited for forestry and low-density housing (*fig. 12*). This land is moderately sloping and has moderate erosion hazard. Careful design and construction practices must be followed. These lands of limited extent occur as scattered areas of moderately steep mountain slopes.

Figure 11. – Subclass 1c land is in the background of a typical view of the glaciated crest of the Sierras at Emerald Bay.

Figure 12. – Class 4 land showing typical vegetation is found near Trout Creek. Rill erosion is evident.

Lands That Are Most Tolerant to Urban-Type Uses

Capability classes 5, 6 and 7 include land suitable for urbanization and other uses. The range in capability from 5 to 7 indicates increasing tolerance for use and decreasing problems and limitations in using the land. About 14 percent of the total area of the basin (28,560 acres) is included in these three classes.

Class 5 land (brown on map) is moderately well suited for urbanization, forestry, and intensive recreation. This land is flat to moderately sloping and has little or no surface erosion problem. Some limitation of use is required by slope and runoff hazards, as improper use and management may cause severe gully erosion. Maintenance and improvement of drainage will be a continued need on much of this land. More intensive application of special conservation practices is needed than on class 6 land. This land is chiefly located in flat-lying areas around the margin of the lake.

Class 6 land (yellow on map) is well suited for urbanization, active recreation, and forestry uses (*fig. 13*). It has some limitations such as minor slope or drainage problems, which influence the manner of development. Easily applied conservation practices are required for safe and maximum utilization of class 6 land.

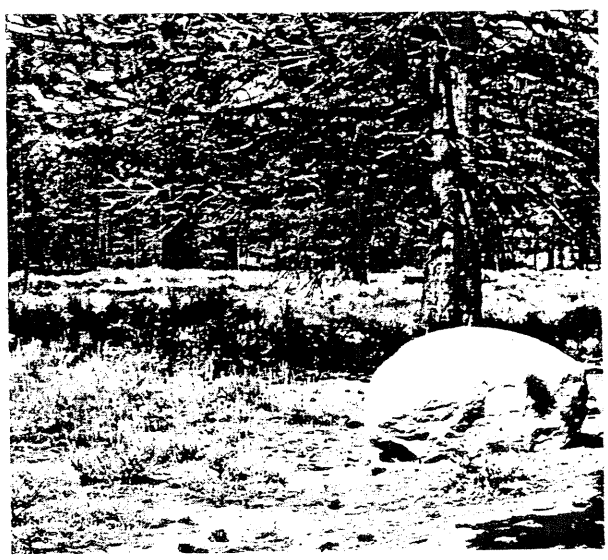

Figure 13. – Class 6 land may be seen in El Dorado County.

It is made up mostly of gently sloping land around the north side of the basin.

Class 7 land (red on map) is very well suited for urbanization, active recreation, or forestry uses. The soil is deep and supports a dense forest cover. It is nearly level and has little or no erosion problem. Drainage is good and the soil has a good capacity for supplying moisture and nutrients for plant growth. Although class 7 land does not have any special problems or limitations for use, it does require good conservation practices to control runoff water and prevent soil loss. Only about 2 percent (3,030 acres) of the total area of the basin is in class 7. All of this land is in the South Lake Tahoe area.

Allowable Impervious Cover

To transform the limitations on land-surface modification for each land capability class into a single numerical index that characterizes development capacity, each class is assigned a numerical value representing the percentage of each area that can be used for impervious cover if environmental balance is to be maintained. Recommended land coverage by capability class is as follows:

Capability class	Allowable percentage of impervious cover
7	30
6	30
5	25
4	20
3	5
2	1
1	1

The numerical rating was arrived at by means of the analysis of hazard factors; recent studies of rates of erosion, sedimentation, and flooding in the Tahoe area (Desert Research Institute 1969, Glancy 1969 and 1971, Haupt 1967, Hussain et al. 1969, Meeuwig 1971, State of California 1969, U. S. Department of Agriculture 1972); field observations of land response to past development; conversations with persons working on similar problems in various parts of the United States (H. P. Guy, S. E. Rantz, R. M. Rice, A. M. Spieker, oral commun., 1971); and results of studies on the

effects of impervious surfaces elsewhere (Anderson 1970, Antoine 1964, Guy 1965 and 1970, Harris and Rantz 1964, Leopold 1968, Lull and Sopper 1969, Martens 1968, O'Bryan and McAvoy 1966, Seaburn 1969, State of California 1971, University of Pennsylvania 1968, Vice, Guy and Ferguson 1969, Wolman and Schick 1967).

Control of impervious surface alone does not solve all environmental problems. It is deemed, however, to be the most critical element in the land disturbance that has created the basic environmental problems facing the Lake Tahoe basin – water quality degradation, flooding, and soil erosion. It is also considered the most accurately measurable and constant expression of development impact.

APPLICATION OF THE CLASSIFICATION TO PLANNING

The classification system should provide a regional framework for planning by which land uses consistent with the natural capabilities and limits of the land in the Tahoe basin may be identified. Such uses may then be expected to result in only a minimum of environmental damage.

This study does not suggest that development should necessarily occur on the locations shown. It merely indicates which lands are compatible with a number of alternative uses. In addition, because of the small scale of the map and the maps from which it was compiled, land capability levels within individual map units may not be uniform. For example, flat valley floors locally contain riparian zones along stream courses that meet the criteria for class 1b, although shown on the map as class 7. It is therefore necessary that the final land capability classification for individual parcels be based on detailed site evaluation and more detailed application of the classification criteria.

The land capability map does not indicate which lands should or should not be developed to preserve scenic or other values. Similarly, specific safety hazards for construction resulting from fire, landslides, and seismic shaking are not shown.

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Appendix

CAPABILITY RANKING BY SOIL TYPE

Map symbol	Soil name	Capability class	Allowable percentage of impervious cover
Be	Beaches	1b	1
CaD	Cagwin-Rock outcrop complex, 5 to 15 percent slope.	4	20
CaE	Cagwin-Rock outcrop complex, 15 to 30 percent slope.	2	1
CaF	Cagwin-Rock outcrop complex, 30 to 50 percent slope.	1a	1
Co	Celio gravelly loamy coarse sand	1b	1
EbC	Elmira gravelly loamy coarse sand, 0 to 9 percent slope.	6	30
EbE	Elmira gravelly loamy coarse sand, 9 to 30 percent slope.	4	20
EcE	Elmira stony loamy coarse sand, 9 to 30 percent slope.	4	20
EfB	Elmira-Gefo loamy coarse sand, 0 to 5 percent slope.	7	30
Ev	Elmira loamy coarse sand, wet variant	1b	1
Fd	Fill land	1b	1
FuD	Fugawee very stony sandy loam, 2 to 15 percent slope.	5	25
FuE	Fugawee very stony sandy loam, 15 to 30 percent slope.	3	5
GeC	Gefo gravelly loamy coarse sand, 2 to 9 percent slope.	6	30
Ged	Gefo gravelly loamy coarse sand, 9 to 20 percent slope.	4	20
Gr	Gravelly alluvial land.	1b	1
GsF	Graylock extremely stony loamy coarse sand, 30 to 50 percent slope.	1a	1
IgB	Inville gravelly coarse sandy loam, 0 to 5 percent slope.	5	25
IsC	Inville stony coarse sandy loam, 2 to 9 percent slope.	6	30
IsD	Inville stony coarse sandy loam, 9 to 15 percent slope.	4	20
IsE	Inville stony coarse sandy loam, 15 to 30 percent slope.	4	20

Map symbol	Soil name	Capability class	Allowable percentage of impervious cover
JaC	Jabu coarse sandy loam, 0 to 9 percent slope.	5	25
JaD	Jabu coarse sandy loam, 9 to 20 percent slope.	3	5
JbD	Jabu coarse sandy loam, seeped, 2 to 15 percent slope.	3	5
JeB	Jabu coarse sandy loam, shallow variant, 0 to 5 percent slope.	5	25
JeD	Jabu coarse sandy loam, shallow variant, 5 to 15 percent slope.	3	5
JhC	Jabu stony sandy loam, moderately fine subsoil variant, 2 to 9 percent slope.	5	25
JgC	Jabu sandy loam, moderately fine subsoil variant, 0 to 9 percent slope.	5	25
JtD	Jorge-Tahoma cobbly sandy loam, 2 to 15 percent shope.	6	30
JwD	Jorge-Tahoma very stony sandy loam, 2 to 15 percent slope.	6	30
JwE	Jorge-Tahoma very stony sandy loam, 15 to 30 percent slope.	4	20
JwF	Jorge-Tahoma very stony sandy loam, 30 to 50 percent slope.	2	1
Lo	Loamy alluvial land.	1b	1
Mh	Marsh.	1b	1
MkB	Meeks gravelly loamy coarse sand, 0 to 5 percent slope.	5	25
MkD	Meeks gravelly loamy coarse sand, 5 to 15 percent slope.	3	5
MmB	Meeks stony loamy coarse sand, 0 to 5 percent slope.	5	25
MsD	Meeks very stony loamy coarse sand, 5 to 15 percent slope.	3	5
MsE	Meeks very stony loamy coarse sand, 15 to 30 percent slope.	1a	1
MsG	Meeks very stony loamy coarse sand, 30 to 60 percent slope.	1a	1
MtE	Meeks extremely stony loamy coarse sand, 15 to 30 percent slope.	1a	1
MtG	Meeks extremely stony loamy coarse sand, 30 to 60 percent slope.	1a	1
MxF	Meiss cobbly loam, 9 to 30 percent	1c	1
MsF	Meiss cobbly loam, 30 to 50 percent slope.	1c	1
Px	Pits and dumps	1c	1
Ra	Rock land.	1c	1
RcF	Rock outcrop-Cagwin complex, 30 to 50 percent slope.	1a	1

Map symbol	Soil name	Capability class	Allowable percentage of impervious cover
RcG	Rock outcrop-Cagwin complex, 50 to 70 percent slope.	1a	1
RtF	Rock outcrop-Toem complex 30 to 50 percent slope.	1a	1
RtG	Rock outcrop-Toem complex, 50 to 70 percent slope.	1a	1
Rx	Rock outcrop and rubble land.	1c	1
ShE	Shakespeare gravelly loam, 9 to 30 percent slope.	1a	1
SkF	Shakespeare stony loam, 30 to 50 percent slope.	1a	1
Sm	Stony colluvial land.	1c	1
TaD	Tahoma stony sandy loam, 2 to 15 percent slope.	6	30
TbD	Tahoma very stony sandy loam, 2 to 15 percent slope.	6	30
TcB	Tallac gravelly coarse sandy loam, seeped, 0 to 5 percent slope.	5	25
TcC	Tallac gravelly coarse sandy loam, seeped, 5 to 9 percent slope.	5	25
TdD	Tallac stony coarse sandy loam, 5 to 15 percent slope.	5	25
TeE	Tallac very stony coarse sandy loam, 15 to 30 percent slope.	3	5
TeG	Tallac very stony coarse sandy loam, 30 to 60 percent slope.	1a	1
TkC	Tallac very stony coarse sandy loam, seeped, 2 to 9 percent slope.	5	25
TmE	Tallac gravelly coarse sandy loam, shallow variant, 9 to 30 percent slope.	1a	1
TmF	Tallac gravelly coarse sandy loam, shallow variant, 30 to 50 percent slope.	1a	1
TrE	Toem-rock outcrop complex, 9 to 30 percent slope.	1a	1
TrF	Toem-rock outcrop complex, 30 to 50 percent slope.	1a	1
UmD	Umpa very stony sandy loam, 5 to 15 percent slope.	5	25
UmE	Umpa very stony sandy loam, 15 to 30 percent slope.	3	5
UmF	Umpa very stony sandy loam, 30 to 50 percent slope.	1a	1
WaE	Waca cobbly coarse sandy loam, 9 to 30 percent slope.	3	5

Map symbol	Soil name	Capability class	Allowable percentage of impervious cover
WaF	Waca cobbly coarse sandy loam, 30 to 50 percent slope.	1a	1
WcE	Waca-rock outcrop complex, 9 to 30 percent slope.	3	5
WcF	Waca-rock outcrop complex 30 to 50 percent slope.	1a	1