Hillside Housing In Taipei

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MASTER OF ARCHITECTURE

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HILLSIDE HOUSING IN TAIPEI

BY
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THESIS

Submitted in Partial Fulfillment of the
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ABSTRACT OF THESIS

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ABSTRACT

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This study presents an overview of the needs and the problems involved in hillside housing, concentrating on the example of Taipei, Taiwan. Due to population growth and mountainous geographic conditions, hillside dwellings are being developed now and could become necessary in other countries in the same situation. It examines the ways in which housing on slopes is different from housing on flat land and analyzes the problems involved on sloping-site housing.

In brief, this report accomplishes these things:

1. Analyzes the problems involved on sloping site housing.
2. Develops a methodology for planning criteria.
3. Recommends directions for further research which will be necessary for a comprehensive development of qualitative value in the hillside housing planning process.

This study does not attempt to be definitive or conclusive. The aim of this study was to construct a tool for problems inherent in the sloping site.

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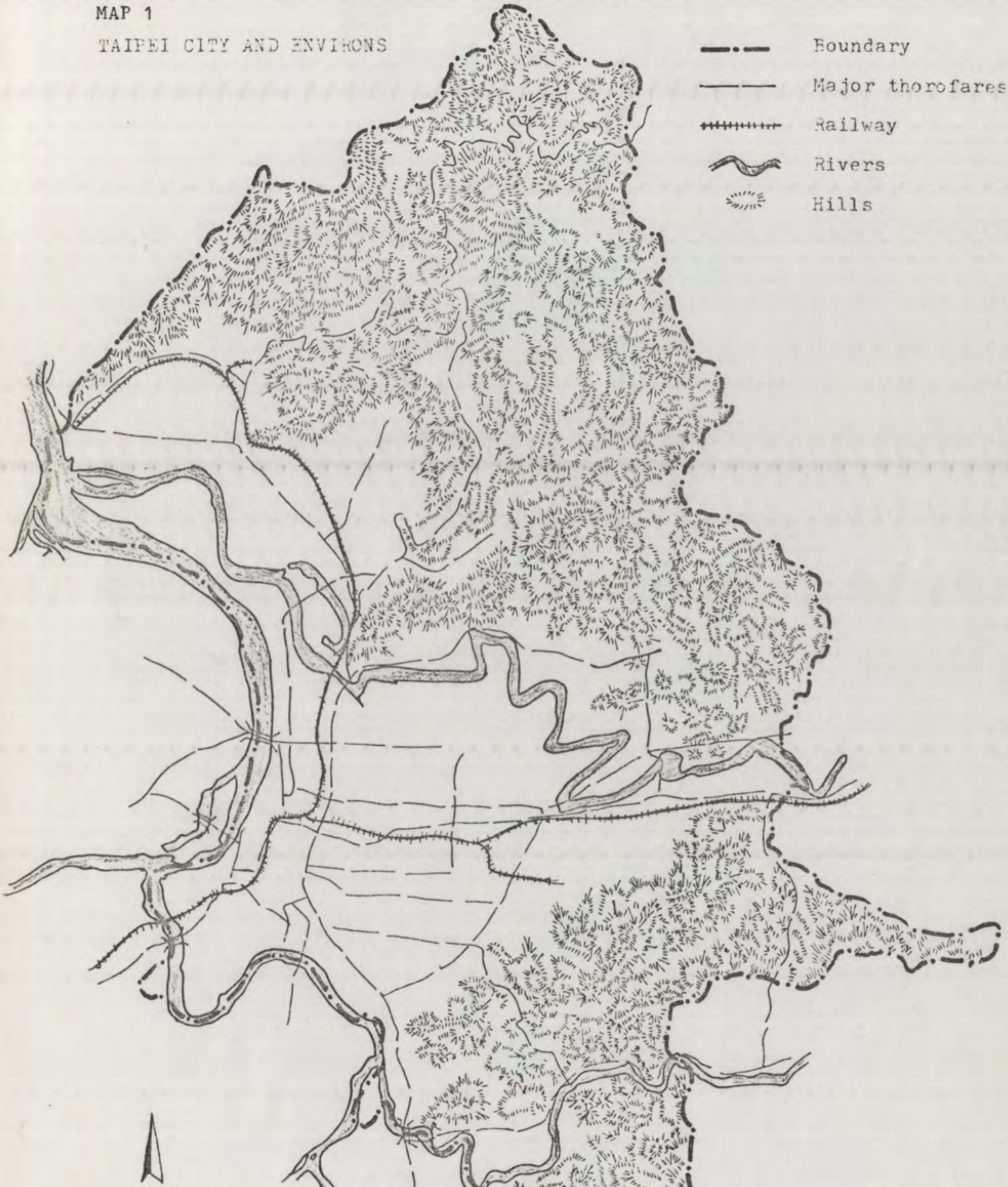
I. INTRODUCTION

Each year millions of acres of land are converted from agricutural use to urban use. These changing acres are the sites for the new houses, shopping centers, schools, industrial parks, highways and airports needed by our growing population and changing life style. Unless more efficient agricultural techniques are developed, which seems unlikely, more population will require more agricultural land for food production. Therefore, the land shortage will become more and more serious, especially in Taiwan, where most areas are mountainous, and most cities are surrounded by mountains. Assuming that we can't prevent the growing population and the city from expanding and we can't afford a lot of flat land for development, one solution is to develop hillside housing for the growing population.

Hillside housing is different from city dwelling in the flat, because of its slope topography. The slope will influence the climate, the utilities, drainage, access and erosion control, but it certainly has many great advantages. Hillside housing not only takes advantage of the midland slopes that are unsuitable for farming, but it offers a new quality of living environment. Most important of all it leaves the precious space of the plain free for agriculture, industry and traffic. This study will attempt to examine these factors and propose design criteria.

MAP 1

TAIPEI CITY AND ENVIRONS



GENERAL BACKGROUND
IN TAIPEI

II. GENERAL BACKGROUND IN TAIPEI

A. City expansion

1. Population growth

Asia and Southeast Asia have one of the highest population growth rates in the world. In 1970 United Nations calculated the average annual rate of increase at about 2.3% in Asia. This rapid increase still remains high because of resistances to reduce family size due to religious and social attitudes.

The rate of population growth in large cities has been very high. In 1900, cities of 100,000 inhabitants and over in Asia accounted for a population of 19.4 million, but fifty years later these large cities contained 105.6 million, an increase of almost 450 percent.

From table 1, it may be noted that most of the selected countries are increasing their urban population at a rate of more than five percent yearly. In Taiwan there is an annual increase of 4.9% in urban population growth and 3.1% in rural population growth. The capital cities of Asian countries have been experiencing the most rapid growth of all the urban areas. In 1966 Taipei had a population of

Table 1. Urban and Rural Population in 1950-1960 (in thousands)

Countries	Population 1950			Population 1960			% Urban		Average annual rate of increase per 100 persons 1950-1960		
	Total	Urban	Rural	Total	Urban	Rural	1950	1960	Total	Urban	Rural
Taiwan	7,554	4,067	3,487	10,792	6,230	4,562	53.0	57.7	4.3	4.9	3.1
Hong Kong	---	---	---	2,993	2,292	701	--	76.6	---	---	---
India	356,742 (1951)	61,872 (1951)	294,869 (1951)	432,543 (1962)	77,534 (1962)	355,003 (1962)	17.3 (1951)	17.9 (1962)	0.2 ('51-'62)	2.1 ('51-'62)	2.0 ('51-'62)
Japan	83,200	31,203	51,997	93,419	59,333	34,086	37.5	63.5	1.2	9.0	-3.5
Iran	18,772	3,761	15,011	21,719	7,445	14,274	20.0	34.3	1.6	9.8	-0.2
Iraq	5,198	1,903	3,295	6,885	3,001	3,884	36.6	43.6	3.2	5.8	1.8
Israel	1,552 (1951)	1,113 (1951)	439 (1951)	2,150	1,649	501	71.7 (1951)	76.7	4.2 ('51-'60)	3.3 ('51-'60)	1.5 ('51-'60)
Korea	21,502 (1955)	5,263 (1955)	16,239 (1955)	24,989	6,997	17,992	24.5 (1955)	28.0	3.2 ('55-'60)	6.6 ('55-'60)	2.1 ('55-'60)
Singapore	Reported to be urban 100%										
Thailand	20,095 (1956)	1,743 (1956)	18,352 (1956)	26,258	4,779	21,479	8.7 (1956)	18.2	7.6 ('56-'60)	43.5 ('56-'60)	4.0 ('56-'60)
Turkey	20,947	5,244	15,703	27,755	7,308	20,445	25.0	26.3	3.2	3.9	2.9

Source: Demographic Yearbook 1970, New York, United Nations, 1971.

1,450,000 and at present it has about 2,000,000. It's annual rate of population increase is about 5.4% and the population is expected to be 2,558,000 persons in 2000.[1]

2. Migration to the city

The increase in urban population is attributable mostly to migration into cities from rural areas. The reasons are as follows:

- Improvement in agriculture techniques decreases the labor need in the rural areas.
- Concentration of industry in a few urban areas. This makes cities the most important source of employment other than agriculture.
- Concentration of government adminstration and services in the capital. Centralization draws any persons with businese with the government to the city.
- Admiration of urban modern activity. Luxurious living attracts many people who look for jobs in

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1 Government of Taiwan, Projections of Population Growth in Taipei (1964-1996), Urban and Housing Development Committee, CIECD, Taipei, 1967.

the city.

- Most people who wish their children to have a better education move to urban areas because higher education in rural areas is limited, and most schools in the city have better teachers and equipment than the schools in rural areas.
- The growth of a middle class, living almost entirely in urban areas promotes urban growth.[2]

B. Geographic condition

1. Mountainous country

Taipei, the capital city of Taiwan, has a special geographic condition. It is located in the east side of a basin surrounded by mountains with a territory of 272.1 km^2 (104.8 square miles). More than half of the territory is rivers, mountains and flood plain or land otherwise unsuitable for development. 2,000,000 people have been crowded in to 102 km^2 (39.2 square miles) area with a density of 180 person/acre. This average means the land

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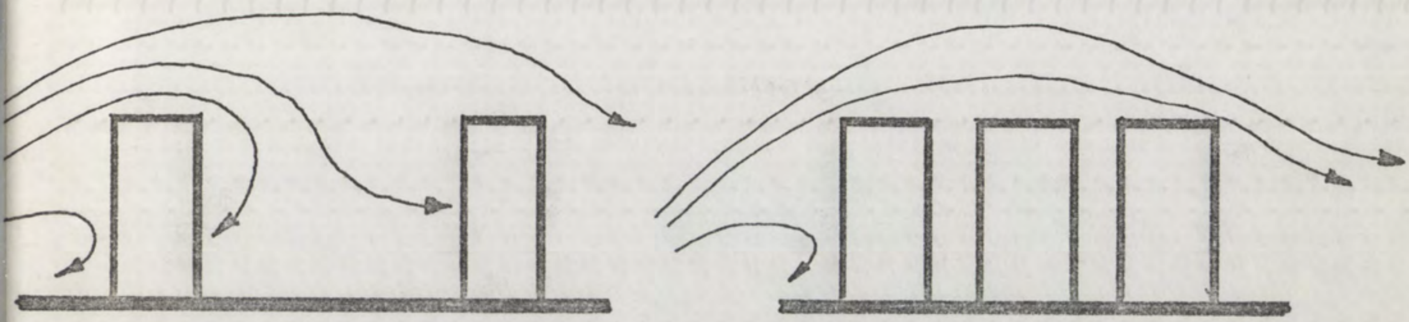
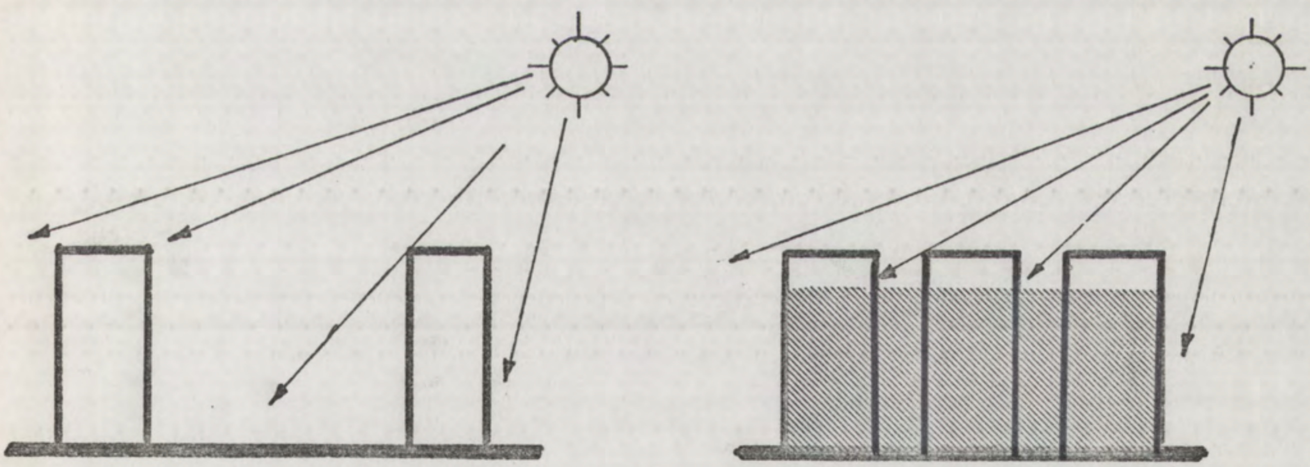
2 Government of Taiwan, Survey of Registered Migrants to and from Taipei City (1958-1967), Urban & Housing Development Committee, CIECD, Taipei, 1968.



air movement in buildings with sufficient space.

air movement in buildings without sufficient space.



light in buildings with sufficient space.

light in buildings without sufficient space. (unpleasant shadow)

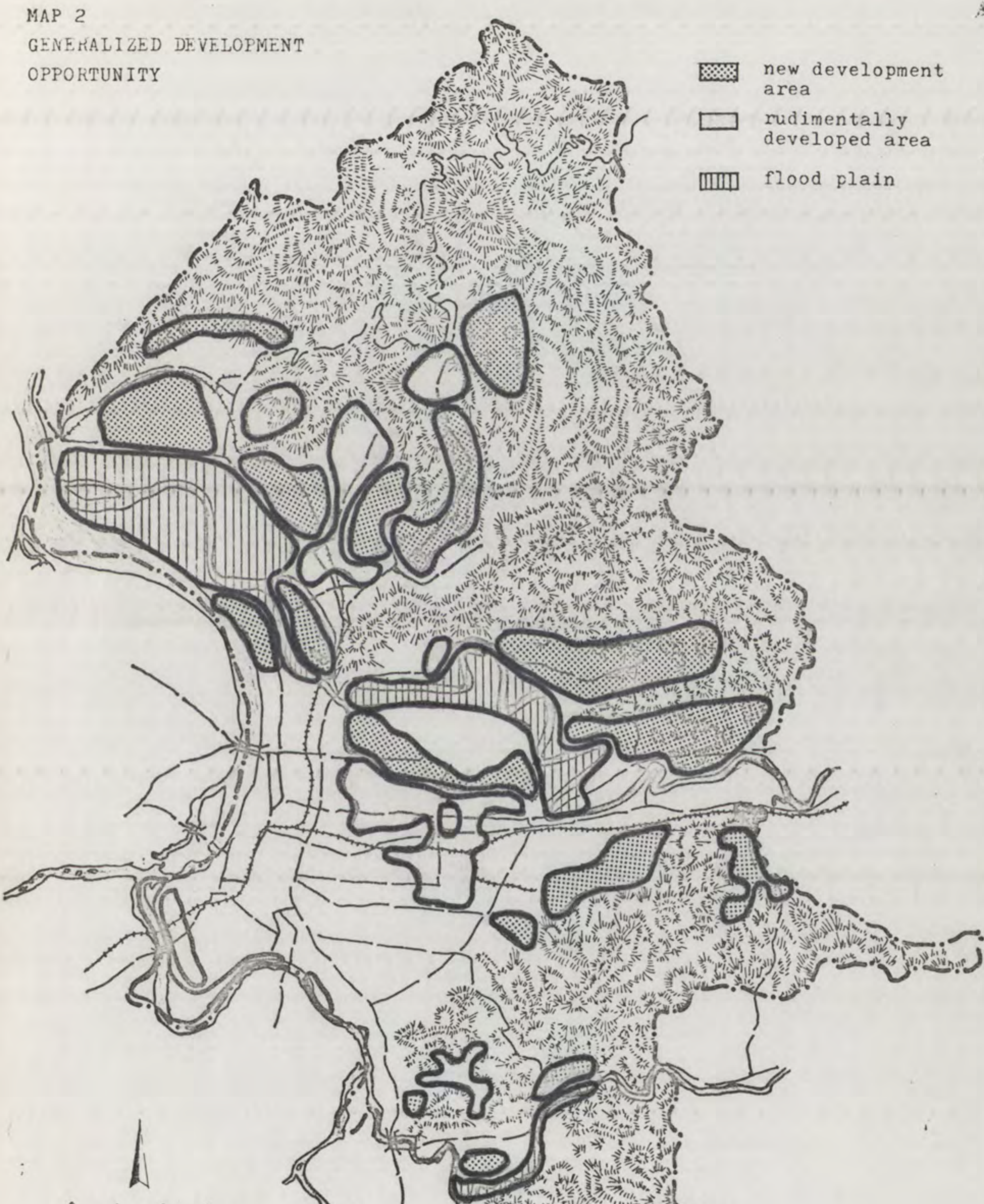
Figure 1: Air movement and natural lighting in buildings

has been over used. The space between buildings is not enough for reasonable air movement, or natural lighting (see Figure 1) and causes traffic congestion, air pollution, etc. It is very important to develop new dwelling areas to decrease the living density.

2. <u>Land shortage</u>

According to the reports from the Urban and Housing Development Committee in Taipei, each year the population will increase 5.4%. This increase means that about 81,000 persons per year will have housing problems, supposing the living density is about 150 person/acre. At this rate, 540 acres of land per year will be needed for dwellings. But due to the geographic limitation mentioned before and the policy of reserving agricultural land, land cost has greatly increased in Taipei; thus, it has been rightly said that the problem of housing in Taipei lies not so much in the scarcity of land but in the scarcity of suitable land. So the U & H D C has suggested 17 areas (see map 2) for suitable development and most of them are hillsides.

MAP 2
GENERALIZED DEVELOPMENT
OPPORTUNITY



COMPARISON OF HILLSIDE VS. CITY LEVEL DWELLING

III. COMPARASION OF HILLSIDE VS. CITY DWELLING

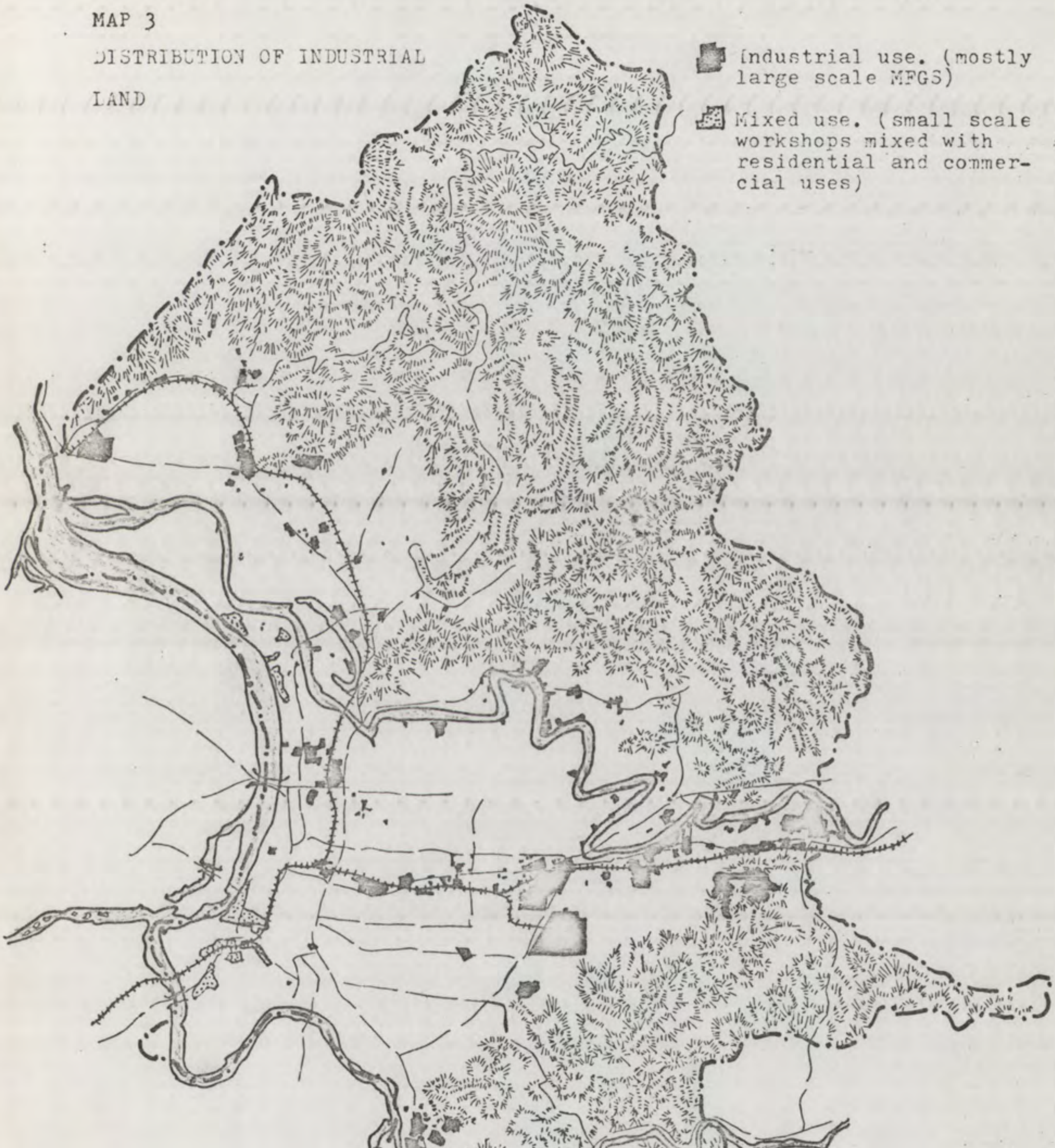
A. Air pollution

Taipei is a modern city. It has air pollution problems as do other cities in the world, and may be more so because there are many factories around the city. (see map 3) Some are light industrial factories operated with electrical power, but some of them, like blacksmith shops, are using coal for energy. Meanwhile, coal operated trains are still used for transportation and hard coal has been used for cooking in slum areas. Thus much coal dust is produced every day. More importantly, the exhaust gas from automobiles, buses, trucks, and motocycles is becoming a more and more serious problem because the number of automobiles has increased very fast. So the major contents of the polluted air are coal dust and exhaust gas.

If the day should be windless, then the polluted air will not be dissipated and will cover urban areas. The people living in the city have to breathe the polluted air. In contrast, because hillside dwellings usually are located in the suburban areas and on higher levels, the air is less polluted there.

MAP 3

DISTRIBUTION OF INDUSTRIAL LAND



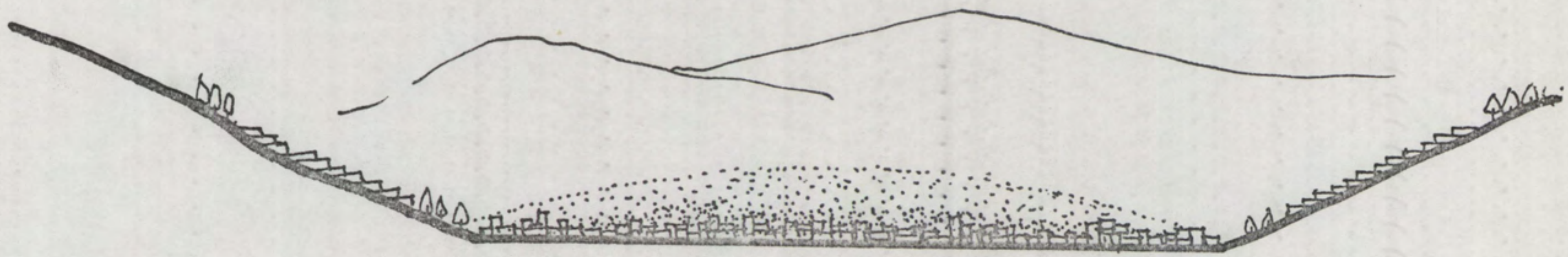
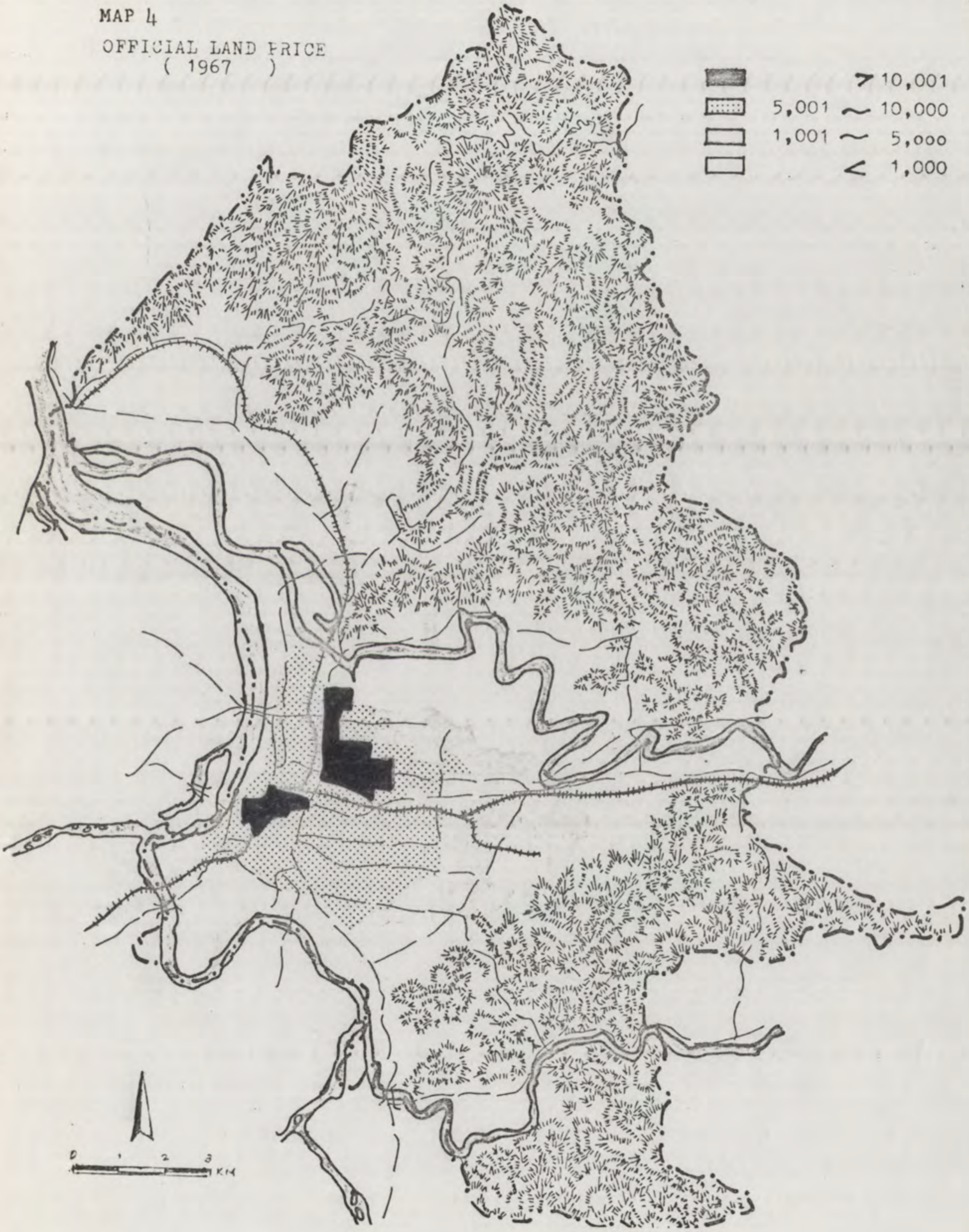


Figure 2: Air pollution in city

B. Cost

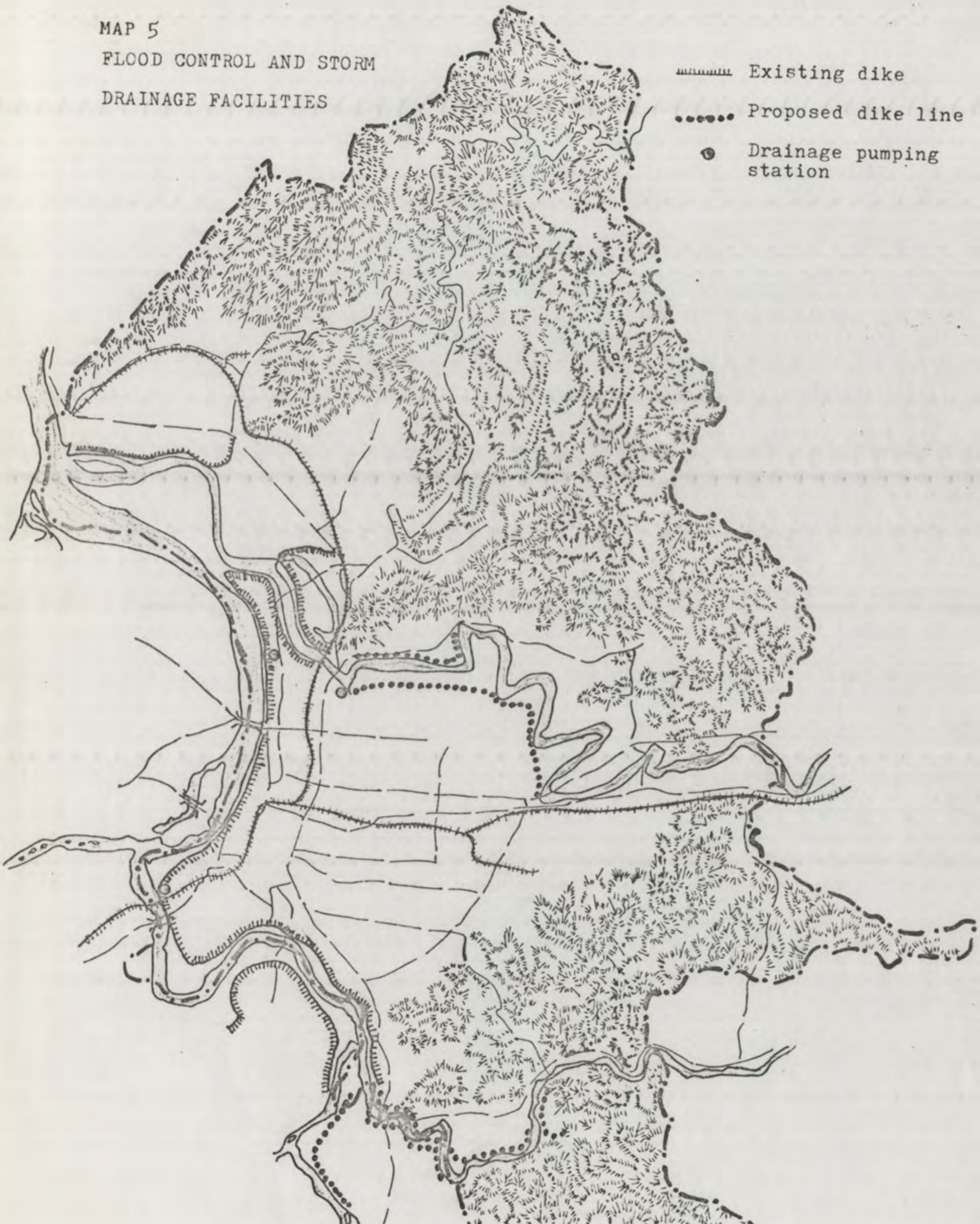
Cost is usually uppermost in the minds of those who make development decisions. Variations in construction costs are caused by fluctuations in the cost of labor and materials, in the skill of construction management and in the construction technology. But variations are also caused by the nature of the site and the finesse of the design. Of course land cost is a great part of the total cost too. Difficult site conditions on a hillside may increase total cost by 50%-100%. However, the cost per person can be decreased by carefully designing for greater densities, arranging the buildings and streets to minimize the street length, minimizing the utility lines of dwelling units, regularizing form and compact arrangements, etc.

In the land cost, hillside dwelling has a great advantage, since land in the city areas is 5 to 10 times more expensive than the hillside land average. (see map 3) The cheaper land cost on hillsides is a great advantage in developing and it may offset the excess cost which is due to the slope site condition.


MAP 4
OFFICIAL LAND PRICE
(1967)
> 10,001
5,001 ~ 10,000
1,001 ~ 5,000
< 1,000
0 1 2 3 KM

C. Flood problem

Taipei, every year has several typhoons through the summer and fall. The typhoon brings lots of rainfall. Due to the geographic conditions the rainfall from surrounding mountain areas flows downhill, gathering in the basin. When the tide is up, the gathering water cannot flow to the river rapidly because the water surfaces are almost on the same level. Therefore drainage pumps must be used to dissipate the gathering water (see map 4). But this kind of method of dissipating gathering water does not work very well, and floods spread all over the city area. Some times the water may be 10 feet deep in the lower areas. This flooding costs a tremendous amount of money every year to clean houses, fix broken areas, repair furniture, repair electric appliances, move the mud from houses, streets and sewers, etc. If the housing is located on the hillside, there will be no such flood problems, because the level is higher than the flat land city dwellings.

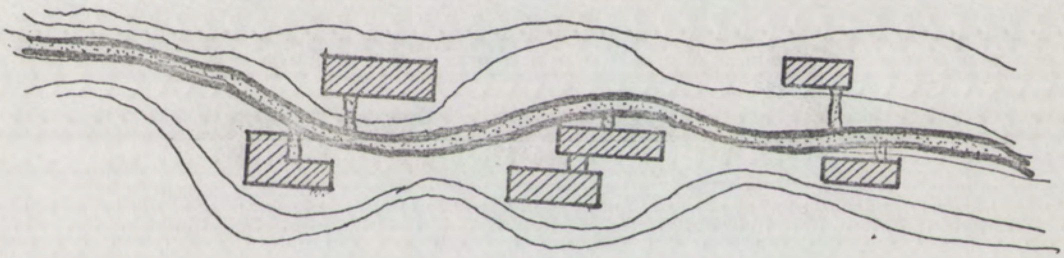

MAP 5
FLOOD CONTROL AND STORM
DRAINAGE FACILITIES
Existing dike
Proposed dike line
Drainage pumping
station

D. Character

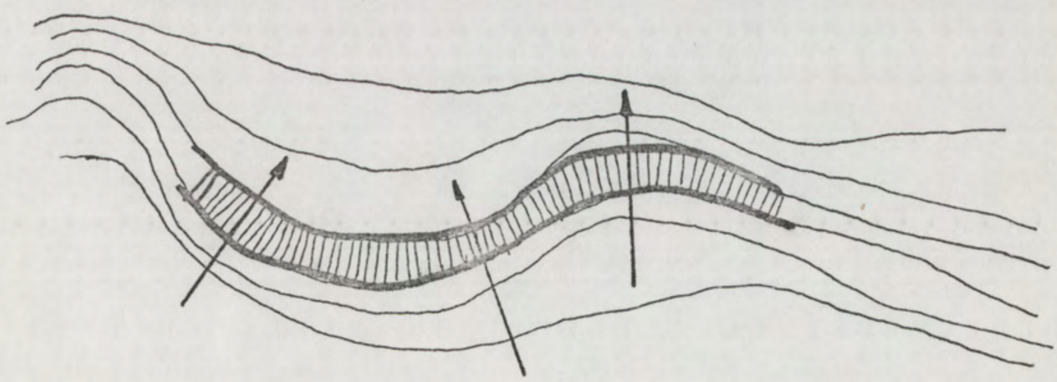
The character differs between hillside and level sites as follow:

Sloping sites

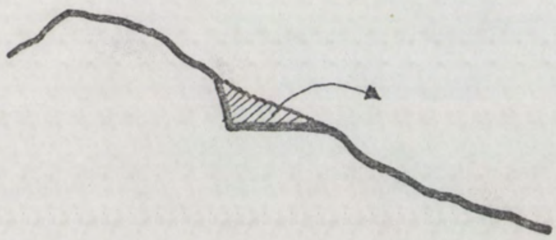
- Contours are a major plan factor. Contour planning is generally required.



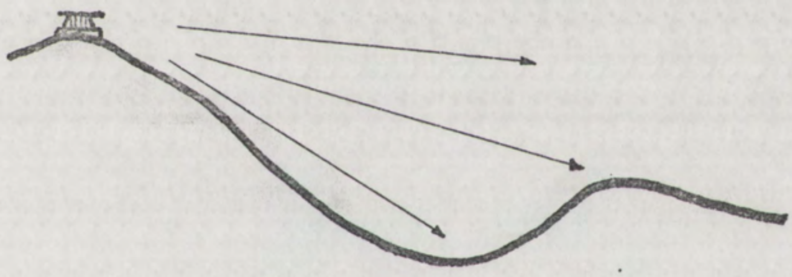
- The areas of relatively equal elevation are narrow bands lying perpendicular to the axis of the slope.



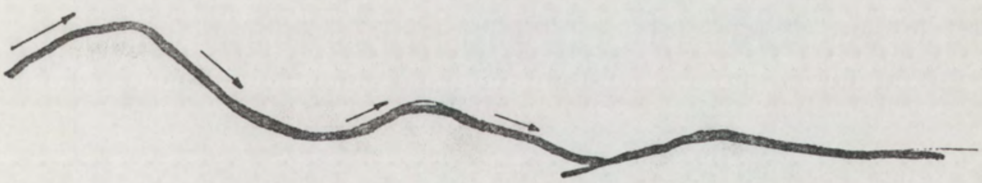
- Sizable level areas are nonexistent. Essential level areas must be carved out of, or projected from, the slope.



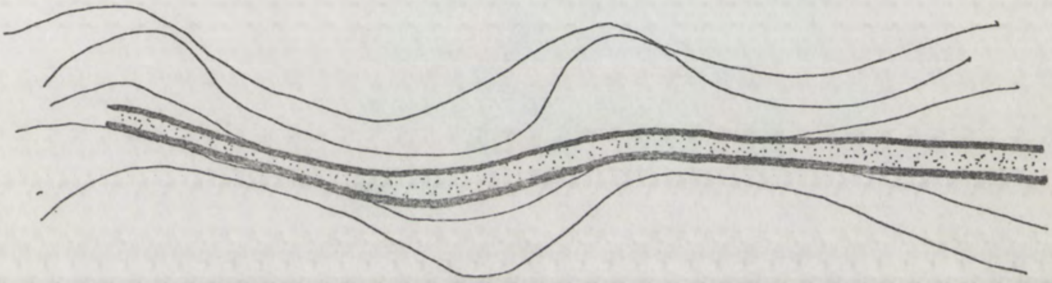
- The top of the slope is most exposed to the elements.



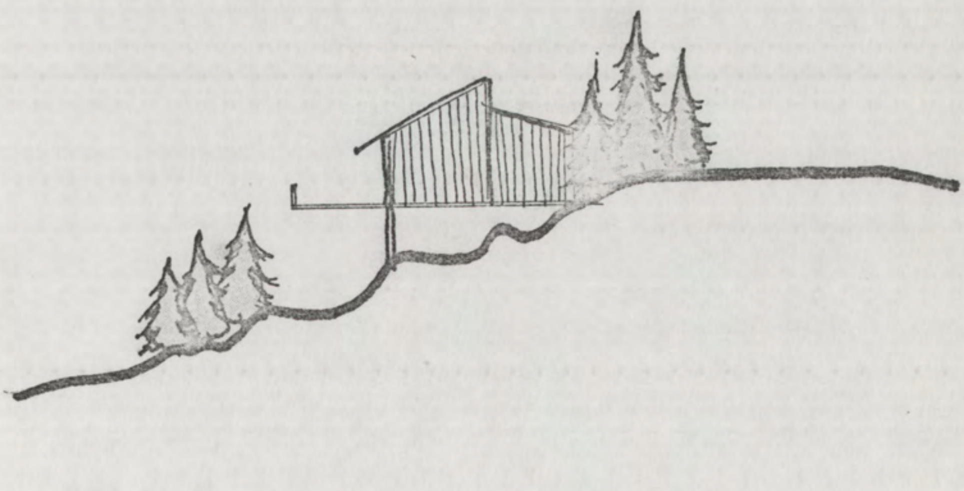
- The essence of slope is rise and fall.



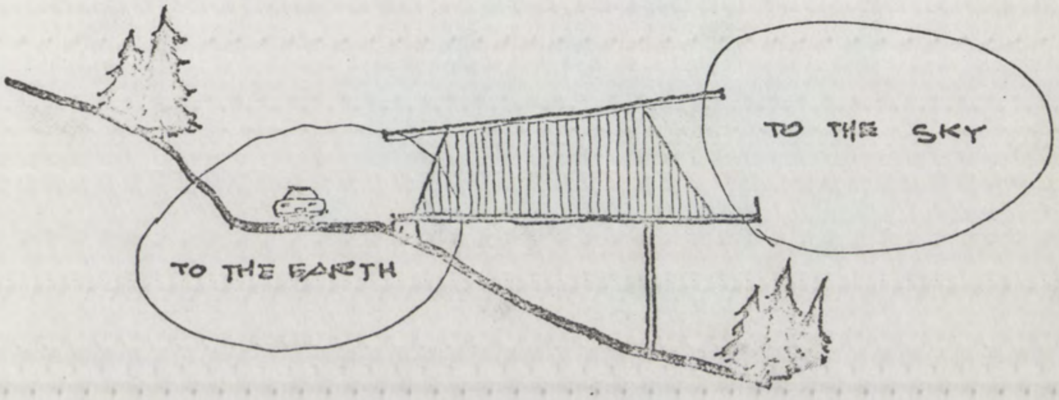
- The slope is a ramp. Ramps and steps are indicated.
- Access is easiest along contours. This fact dictates a normal approach to the project from the sides.



- The pull of gravity is down the slope.
- The sloping site has a dynamic landscape quality. The site lends itself to dynamic plan forms.
- The dramatic quality of a slope is its apparent change in grade.

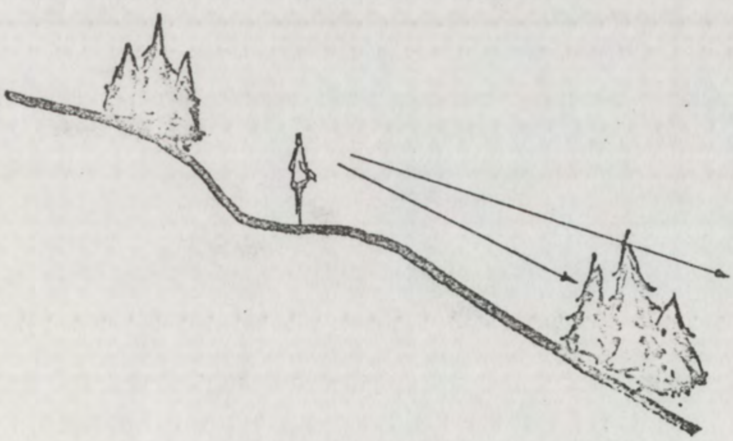


- A slope inherently emphasizes the meeting of earth and air.



- A sloping site affords great interest in views. Artificial site development to create landscape interest may be minimized when a sloping site commands a fine view. Little other site interest may be required.

- The slope is oriented outwards. Plan orientation is normally outward and down.



Level site

- A level site offers a minimum of plan restrictions.
- A level site has relatively minor inherent landscape interest. Plan interest depends on relation of object to object, space to space, and object to space.
- A level site is essentially a broad-base plane.
- A level site has no focal point.
- Lines of approach are not dictated by the topography.
- The site offers little privacy. The creation of privacy is a function of the plan orientation.
- Third dimension is lacking.
- The level site offers no obstruction to lateral planning.
- A level site is monotonous. Interest is in structure rather than in natural landscape.[1]

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1 John Ormsbee Simonds, Landscape Architecture, New York, McGraw-Hill Book Company, Inc., 1961. PP.62-63.

GENERAL PROBLEMS

IV. GENERAL PROBLEMS

A. Slope and climate

Each site has a general climate which it shares with the surrounding region, and a microclimate, a modification of the general climate. The general climate is expressed in a set of average data for the region, covering such phenomena as solar angle, day of sunlight, ranges of temperature and humidity precipitation, and wind direction and force. This information, broken down by major seasons of the year has a basic influence on the entire plan: the orientation of structures and their shielding or exposure to sun, the equipment for cooling or heating, the fenestration, the materials, the cover and planting in general.

The plan modifies the existing climate to approximate an optimun condition. The means for making this approximation will vary with each climate. Unfortunately, it is only too common to bring forms suitable for one climate into another completely different one.

There are surprising variations in the microclimate of a site. Due to cover or topography, wind speed and temperature will vary markedly within a few feet of elevation. The slope of the ground with respect to the sun and the general form of topography affect air movement.

In the tropics, the high angle of the sun tends to minimize the differences between the orientation of slope. Maximum direct radiation is received by the surface which is perpendicular to the direction of the sun, and this depends on latitude, season, and hour of the day. Thus a south slope will receive more sun than flat land, and in midsummer, a northwest wall may even be warmer than a south wall. On a 40° N latitude, the total direct and diffuse radiation on a 10 degree (17 1/2%) slope attains the following approximate percentages of the possible maximum, depending on season and the orientation of the slope.

TABLE 2

Approximate Percentages of Total Direct and Diffuse Radiation on A 10 Degree Slope

Slope Direction	Midsummer	Equinox	Midwinter
North	95%	55%	15%
East or West	100%	60%	25%
South	100%	70%	35%

Source: Kevin Lynch, Site Planning, Cambridge Massachusetts, The M.I.T. Press, 1967.

TABLE 3 (same data)

Approximate Percentages of Total Direct and Diffuse Radiation on A Perpendicular Wall

Wall Face	Midsummer	Equinox	Midwinter
North	40%	15%	5%
East or West	90%	70%	25%
South	50%	95%	100%

Source: Kevin Lynch, Site Planning, Cambridge Massachusetts, The M.I.T. Press, 1967.

The general form of the topography also affects air movement. Wind speeds on the crest of a ridge may be 20 percent greater than those on the flat.

As mountains affect the macroclimate, small differences in terrain can create remarkably large modifications in the microclimate. Cool air is heavier than warm, and at night the outgoing radiation causes a cold-air layer to form near the ground surface. The cold air behaves somewhat like water, flowing toward the lowest points. This "flood of cold air" causes "cold islands," or "cold air puddles." Accordingly, elevations that impede the flow of air affect the distribution of the natural temperatures by dam action;

and concave terrain formations become cold-air lakes at night. The same phenomenon is enlarged when a large volume of cold air flow is involved, as in valleys. On open slopes cold air floods are common nocturnal phenomena. A layer of air near the ground loses its heat by radiation to the night sky. This layer of air flows downhill, streams in open valleys, or is blocked by some "dam" of topography to form a still pool. It is very cold and damp at the foot of long open slopes. Sometimes such air floods can be diverted uphill by barriers, or prevent from pooling by breaching the downhill dam.[1]

If cold air pockets are large enough, and if fog or haze has formed to prevent the sun from warming the ground, they may persist over the next day. Since the air is coldest close to the ground, a situation in which unsual daytime condition is created called an "inversion". Because it is the reverse of the normal daytime condition. The formation is stable because cold air is heavier than

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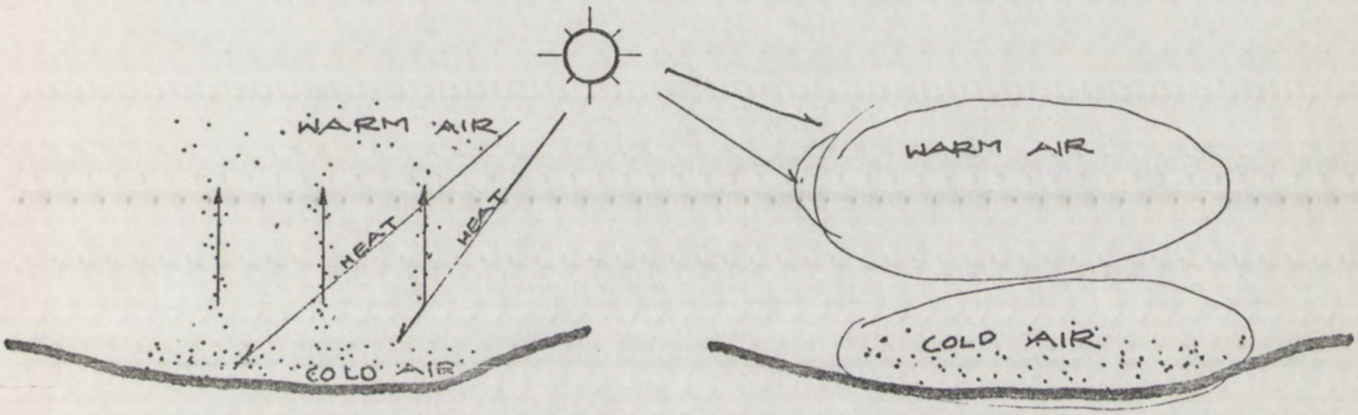
1 Victor Olgay, Design with Climate, Princeton, New Jersey, Princeton University Press, 1973. P.P. 45-46.

warm, and there is none of the customary upward movement of warm, light surface air. If the day should also be windless, then fog and smoke will not be dissipated, and thus smog will collect over urban areas.



In brief, in the temperate zone, the best local climates tend to be on south or southeast slopes, and on upper or middle slopes rather than at their foot or crest.

B. <u>Slope and utilities</u>

Normally, the utilities system would be computed and designed by an engineer, but it is useful for the designer to understand the computation and its implication and try to avoid difficult problems for the engineer in the new development of sloping sites.

Water

Since there is no frost problem in Taiwan, the water supply will present few difficulties. The line may rise and fall with the slope of the surface as long as positive pressures are maintained at the high point.

Electric

Electric power is brought in on primary high-voltage lines, and then is stepped down at transformers to enter secondary low-voltage lines going to points of use.

The conductors may be placed overhead on poles or underground in raceways. Underground distribution may be two to five times more expensive in first cost, but it reduces break age, does not interfere with trees, and provides a better visual environment.

Thus, the electric power supply on sloping sites presents no special problems.

Gas

Gas is piped underground in a system similar to the water distribution network or it can be supplied by gas tanks. The use of gas is not very popular in Taipei because the gas company was established just 5 years ago, the pipe lines are complete in only a small part of city, and the consumers have to pay 50% of the construction of new lines. It would be expensive and impractical to install lines far away from the city center to the suburban area.

The price of using gas in tanks is 25% higher than pipe gas and refilling is required. Usually a 5 member family only needs to refill once a month. Therefore, gas in tanks is a convenient alternative.

Drainage

Utility layouts usually begin with the storm drainage, which is the utility most likely to be significant. The layout of all utilities may show the storm drainage on the grading plan because it is so intimately related to topography.

The storm system is today normally kept separate from the sanitary drainage to minimize the volume that must be treated in sewage disposal and to prevent backing-up of sanitary waste.

The storm system is made up of a drainage surface, a set of open gutters and ditches, and probably a series of underground pipes.

Surface water first flows in a film across the ground, and it is kept spread out as long as possible. The aim is to keep surface water moving, but not so fast as to cause erosion. Allowable slopes therefore depend on the volume of water expected, the surface finish, and the amount of damage that can be done by local flooding. Planted areas and broad paved areas should have a minimum grade of one percent.

Land should slope away from all buildings for ten feet with a minimum grade of two percent.[2]

The storm sewer system is initially laid out in plan, locating the first inlets as far down the slopes as possible, within the limit for flow in the open gutter. The pattern of converging sewers is then arranged so that there is a minimum length of line, and a minimum number of manholes, which are nevertheless placed to be close to all necessary inlets, and to allow straight runs within the right-of way

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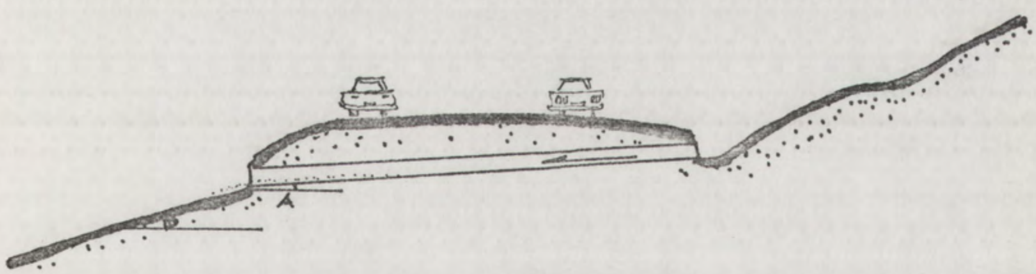
2 Kevin Lynch, <u>Site Planning</u>, Cambridge, Massachusetts, The M.I.T. Press, 1967. P. 193.

between their locations.

A short length of pipe, inserted under a road or other barrier to carry storm water or a small brook, is called a "culvert". It is in effect a fragmentary storm drainage system. Normally they should be straight, should cross the road approximately at right angles, where possible. They are laid at the slope with a maximum grade of eight to ten percent and a minimum grade of one-half percent. The gradient just below the outlet must be at least as steep as the slope above the inlet to prevent silting.



$\angle B \geq \angle A$

Sanitary wastes

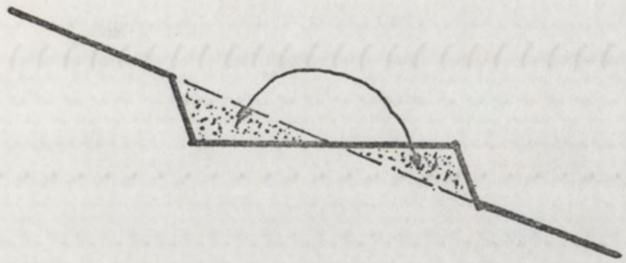
Sanitary wastes, such as those from sinks and toilets, are generally kept out of the storm drains, but are carried down in a system quite similar in form.

If a public disposal plant is not within reach, it is now possible to construct an economical private disposal plant. A small private plant would consist of a septic tank discharging into an underground drain field. This plant should be set several hundred feet from any house and could be economically designed to serve up to 500 dwelling units.

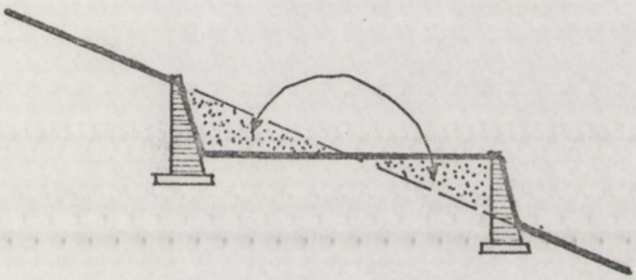
If properly installed, septic tanks should give no future trouble, and are more economical than a sewage system and the small community disposal plant has the advantage that it can later be hooked into a future public system.

C. Slope and structure

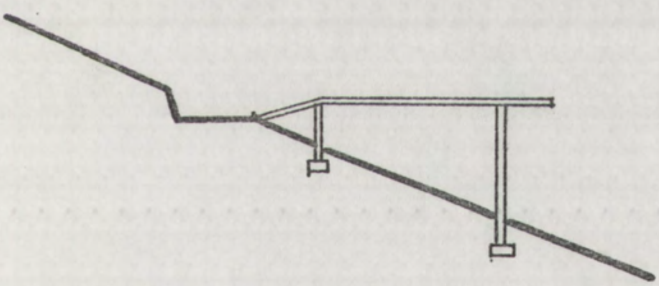
Structure methods on a sloping site should be different from level site, because of it equal elevation are rarely. Therefore, the flat plan is achieved by terracing retaining walls, the supported platform, or cantilever.



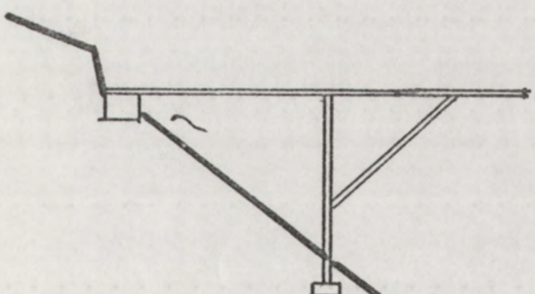
Terracing



Retaining wall



Support



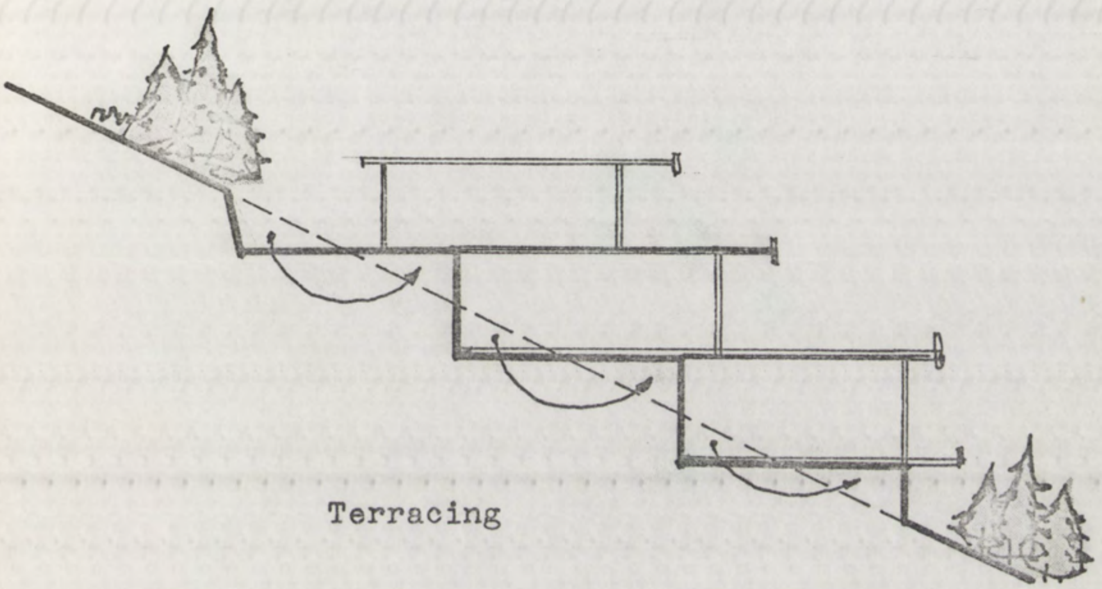
Cantilever

The structure which lies on a sloping site can use one of these means or combine two or three of them to achieve the platform. The selection depends on the material, gradient and site conditions; for example, in a very steep site or rocky site a terracing or retaining wall should be avoid because it would need great quantities of cutting and filling which is very difficult and expensive. Support columns or cantilevers would be an easier and less expensive way to achieve a platform. On the contrary, on a gentle sloping site the earth cut and fill method of forming a terrace would be easier than using a cantiliver or supporting column.

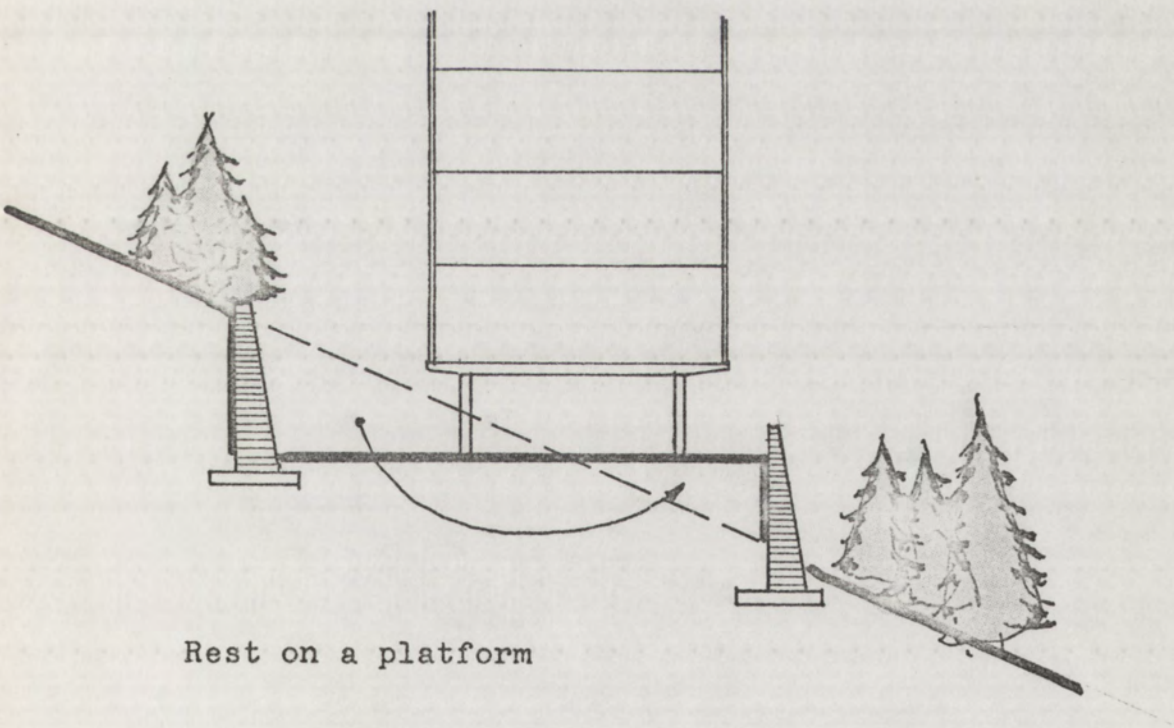
Following are the general structural methods used on the sloping site.

1. Terracing & retaining wall

Terracing usually needs earth cut and fill and is used on a gentle slope with a retaining wall. The structures may hug the slope continuously. Or rest on a platform to obtain a higher density.



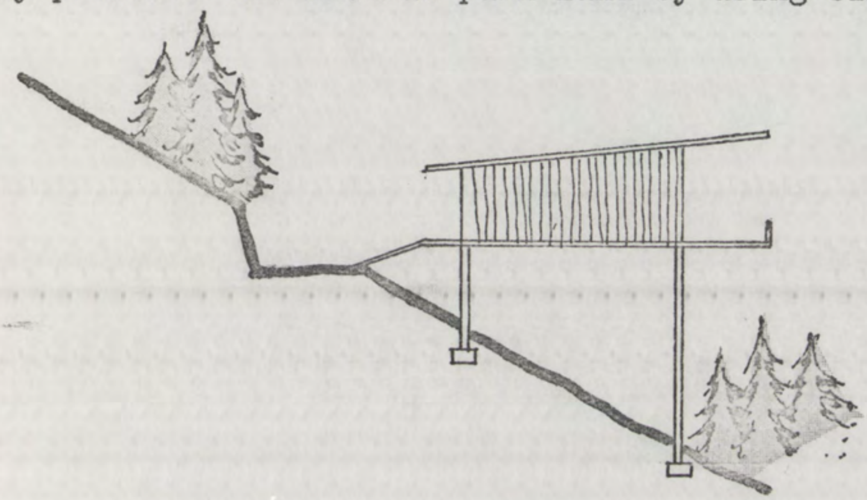
Terracing



Rest on a platform

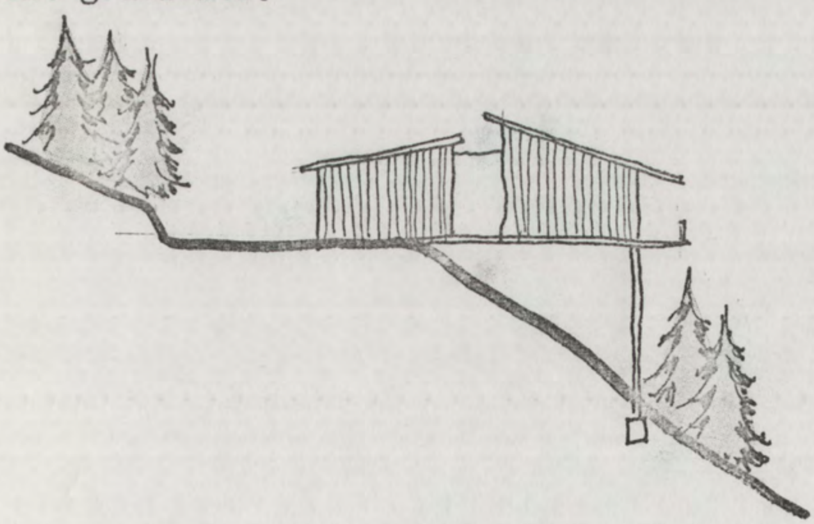
2. Vertically supported

Vertically supported methods are used on steep slopes. The structures may stand completely free. It is the best way preserve the natural park land by using single units.



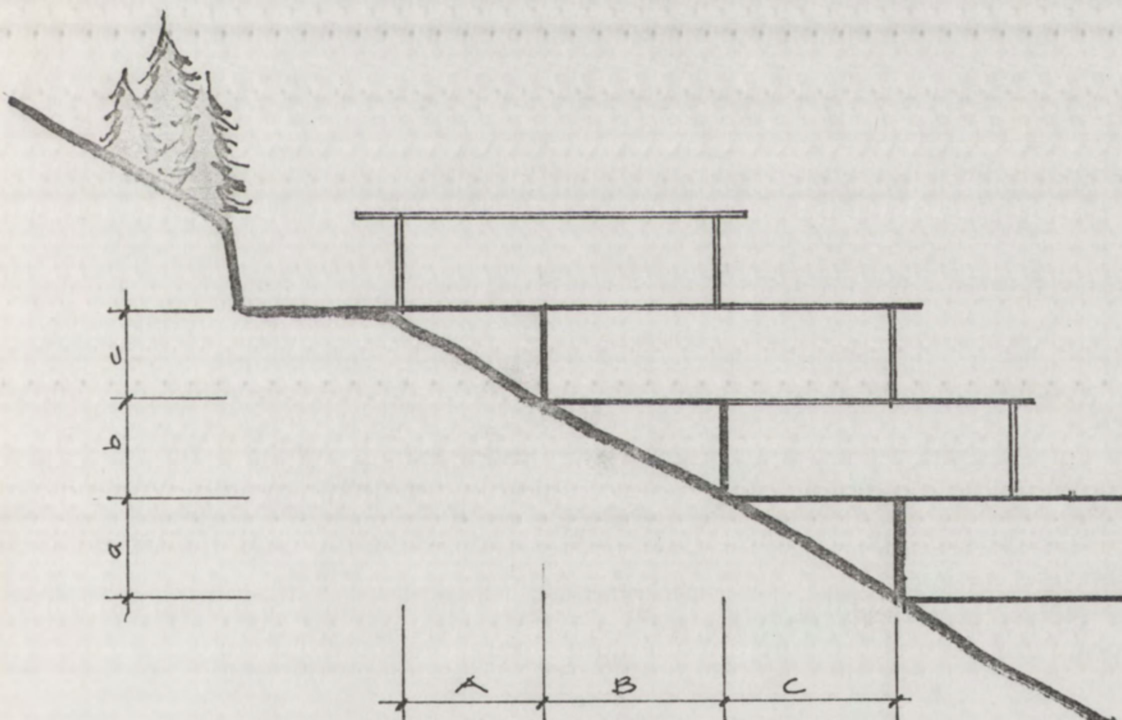
3. Terracing and vertically supported combination

This method can be used in a sloping site with different gradients.



4. Vertical support wall method

Vertical support wall method would need neither supporting column nor earth cut and fill; each level can be adjusted to fit the site by adjusting the distance between the support walls. For example, the distance between the support walls on the gentle slope would be longer and it would be smaller on a steep slope.

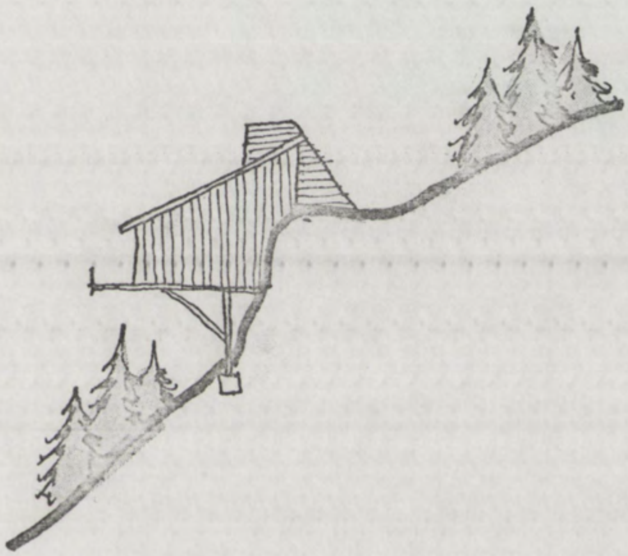


$a = b = c$

$A \neq B \neq C$

5. <u>Cantilever</u>

Cantilever are used in the situation of difficult foundation or when the slope is very deep.

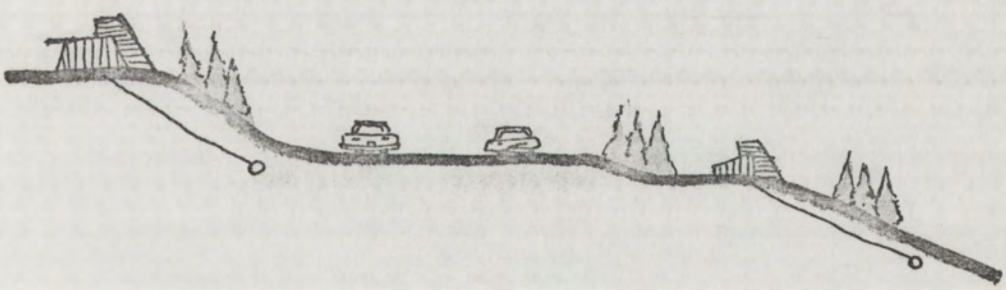


D. <u>Slope and access</u>

There are three basic types of road layouts on the sloping site:

1. A road lying slong the contours: it usually permits level foundations for buildings fronting on it.

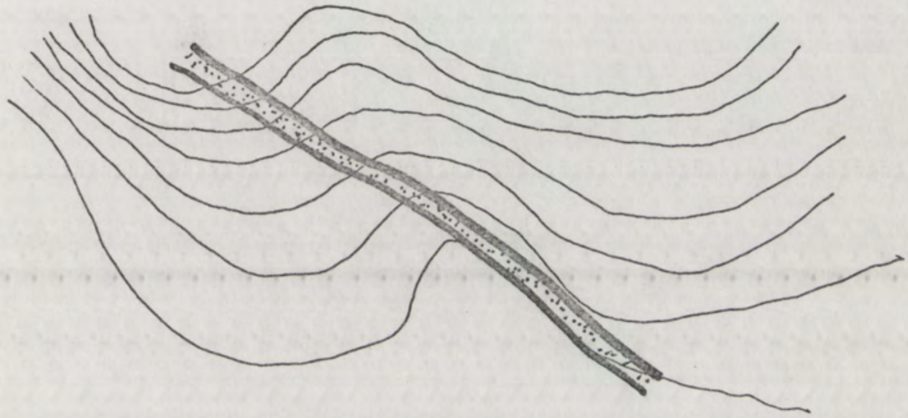
However, if the cross slope is sharp, access to these buildings may be labored, sewers are difficult to reach, and the visual space is lopsided. In this case it becomes necessary to widen the road to take up the cross slope and to dissociate the facing buildings visually, or to use separate utilities for the lower structures, or one-sided frontage, or special building types on the lower side which are entered at an upper story. Therefore, contour-following roads should normally be kept back from the brow of a hill if double frontage is intended.



2. Roads perpendicular to the contours avoid some of the above problems. New problems are introduced. First, foundations have to be stepped, and street and utility gradients become too steep. Second, rear lots in cross slopes require substantial terracing. It is, however, possible to use special step-down building types in a dramatic way.

3. Roads diagonal to the contours should be avoided, unless it is absolute necessary, since these contour plots are the most difficult to use, and should be avoided except where slopes are gentle,

or where they are so steep that neither parallel nor perpendicular roads will serve.



The vertical alignment of the centerline of a road is made up of straight tangents--constant upgrades or downgrades--with vertical curves at the junctions. These vertical curves are parabolic rather than circular. Parabolic curves are used because they are easy to set out in the field, while still making a smooth transition between the intersecting grades. By convention, grades are given as positive percentages when uphill in the direction of increasing numbers in the stationing, nagative when downhill.

The minimum grade of tangents is 0.5 percent so that water will drain off the road surface, or 0.25 percent if construction is done with particular care. The maximum grade of streets depends on design speed. Maximum grades should not be long sustained. A passenger car cannot stay in high gear if the grade is continuously above seven percent, while a large truck must shift down on sustained grades of over three percent. Maximum grades are somewhat flexible, depending on winter conditions and on local habits due to prevailing terrain. Where icing is severe, anything over 10 percent may be too steep, (in San Francisco regulations allow grades up to 15 percent on minor streets). A 17 percent sustained grade is the most that a large truck can climb in lowest gear.

Where the algebraic difference between tangents is over nine percent, the long low modern cars will strike the road surface in passing the break in grade.[3]

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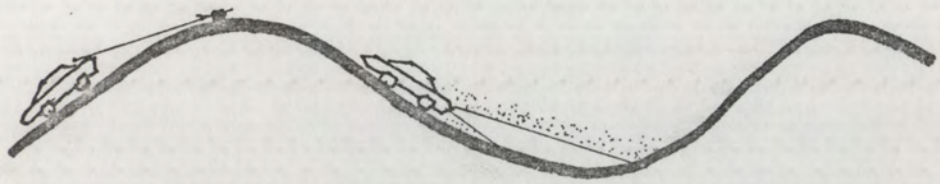
3 Ibid P. 188.

Therefore, vertical curves must be used in driveways at this or higher differences, of sufficient length to prevent such a grade change within a six-foot length. A curve which is one foot long for each one percent of algebraic difference in grade will accomplish this.

The required length of vertical curves in a street is controlled by "roadability"--the avoidance of an unpleasant jolt in the vehicle making the grade transition caused by an excessive acceleration or deceleration of vertical velocity--and by the need to maintain adequate sight distance. For roadability, the minimum length of the curve for each one percent of algebraic difference in grade of tangents depends on design speed.

Minimum forward sight distance must be maintained throughout the vertical as well as the horizontal alignment. This is computed as being vision from a point four feet above the road to a point four inches above the road, and may be scaled from the profiles. Sight distance may sometimes require longer vertical curves at summits than needed for roadability. In sag curves the resulting length of headlight beam must also be checked to see that it is equal to minimum sight distance.



For reasons of safety, sharp horizontal curves should be avoided on high hills, in deep cuts, or at the foot of steep grades. The change in direction on a reverse curve should not occur when going over a summit. Where a horizontal curve occurs on a grade of over five percent, the maximum allowable percent of grade on the curve should be reduced by one-half percent for each 50 feet that the curve radius is less than 500 feet.

The following table indicates the variation in alignment standards according to design speed. An appropriate design speed for minor residential streets is 25 miles per hour. Maximum grades at the slowest speeds may be increased, but these grades should not be continuous for long stretches.[4]

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4 Ibid., P.191.

TABLE 4

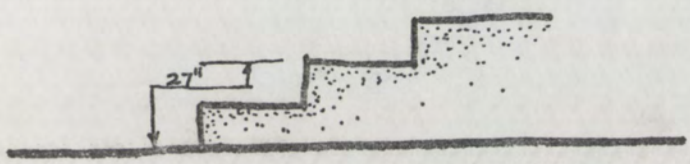
Alignment Standard in Relation to Design Speed

Design speed, in M.P.H.	Minimum radius of horizontal curves in feet	Maximum % of grade	Min.forward sight distance, in feet	Min.length of vertical curve for each 1% change of grade, in feet
20	100	12	150	10
30	250	10	200	20
40	450	8	275	35
50	750	7	350	70
60	1100	5	475	150
70	1600	4	600	200

Source : Kevin Lynch, Site Planning, Cambridge, Massachusetts, The M.I.T. Press, 1967.

Side walk

The maximum grade of sidewalks should be ten percent or less. Short ramps at breaks in grade may go up to 15 percent, however. If steps are used, there must be at least three risers, so that they will be noticed, and accidental falls avoided. A useful rule for proportioning exterior steps is that the height of two risers added to the width of the tread should equal 27 inches. Riser height may vary between 6 1/2 inches as a maximum and 3 inches as a minimum.



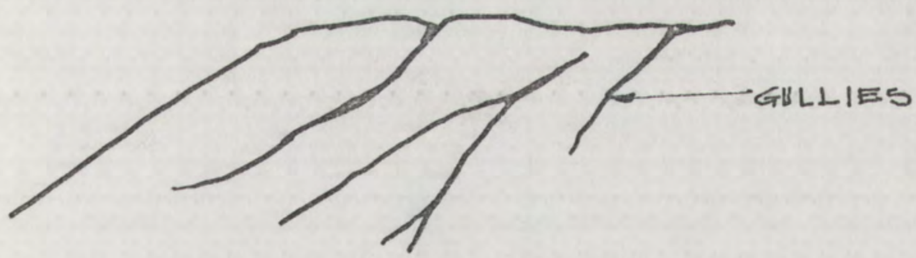
E. Slope and stability

In the sloping site the permanent battle between constructive factors such as vegetation colonization and the destructive forces of erosion often produce an unsuitable landscape.

There are two main kinds of destructive forces in the sloping site; one is surface erosion and the other is deep seated slip.

Surface erosion

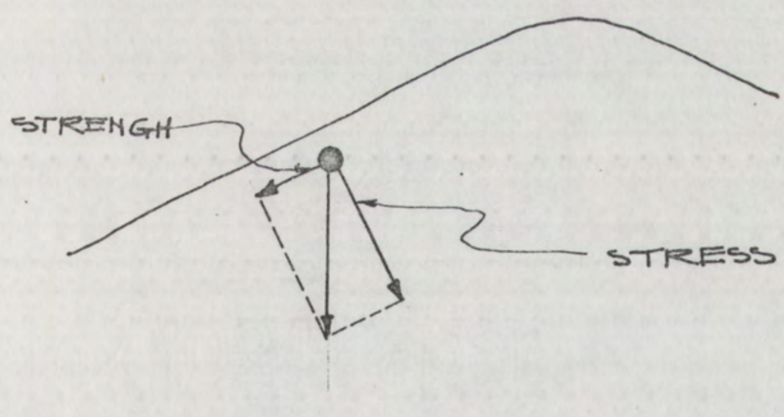
Surface erosion occurs when the intensity of precipitation exceeds the infiltration capacity of the soil, the excess water flowing to drainage channels across the surface or within the very top particles of the soil surface. A rut caused by wheels or human feet can cause a channelling action, thus accelerating the flow of water down the slope and gradually cutting down through the top soil to form rills. If left unattended, these small channels can rapidly become further developed by heavy rains to become gullies. These gullies result in damage by silting of drains and paths at the base of the slope. Such an erosion pattern is most likely to occur in areas where the ground cover vegetation is poorly developed and the soil is light.



In certain instances water washing down over the sloped surface removes surface particles over the whole area instead of in channels. If unattended this situation can result in loss of top-soil organic matter from the whole site making further work in establishing vegetation more difficult.

Subsurface instability

In subsurface instability the slip occurs when the shear stress developing between a layer of the soil exceeds the shear strength. This situation can occur either by an increase in the stress or a decrease in the shear strength.[5]



[5] Newcastle-upon-Tyne University, Landscape Development of Steep Slopes, Newcastle-upon-Tyne, England, Oriel Press, 1972.

The increase of stress can be caused by:

1. Excavation or erosion at the base of the slope.
2. Additional load at the top of the slope caused by new construction.
3. Increase in the weight of the soil by water uptake.
4. By the build-up of water pressure in verticle cracks formed as a result of tension in the slope material.
5. Swelling pressure resulting from differential water absorption following seasonal cracking of shrinkable clay and filling up of the cracks by soil particles.

Reduction shear strength can be caused by:

1. Softening of clay by water uptake, either seasonally or due to change in general hydrology of the area.
2. Surface drying and cracking of clay soil leading to deep penetration of water.
3. In non-cohesive soils, by reduction of the load normal to the plane of shear by reason of buoyancy in the overlying soil resulting from a rise in the water table.

Therefore, most of the slope stability failure is generally caused by water-related factors. Drainage is therefore an important factor to consider when remedial or preventive measure are being planned.

Deep seated instability will require immediate structural remedy which may or may not be assisted by vegetation. The structure designed to support a slope must have adequate provision for through drainage of water. If insufficient drainage is provided, there can be a serious build up of water behind the structure, possibly leading to its total collapse.

Treatment

The treatments of slopes which are tending to slip are as follows:

1. External support

External support can be provided in several ways. Loading of the toe prevents further slipping, but is generally used only as a temporary measure. The construction of retaining walls and piling through the toe of the slip to below the slip surface are more permanent remedies, but they must be large enough in proportion to the size of the bank and must provide for drainage of water through the structure.

2. Removal of weight

The removal of slope material implies altering the profile of the land on which the excess material is spread.

a) Reducing the angle of the slope. (Figure 3-1)

b) Constructing different angles of the slopes. (Figure 3-2) This method can be used where two different types of material are encountered on a slope.

c) Terracing (Figure 3-3)
Creating two shorter slopes with a flat area between.

3. Strengthening the slope

Slips generally occur in cohesive material because the material has become weakened by the increase in water content.

The stress resisting properties of the material can be greatly improved by a reduction in the moisture content. To bring about this improvement, it is necessary to remove the water already in the material and also to prevent

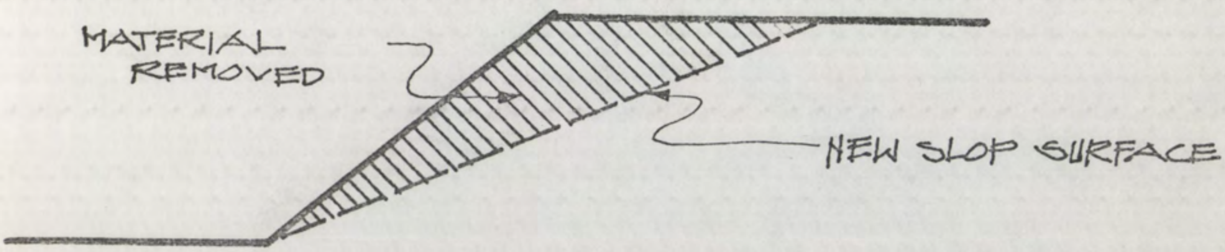


FIG. 3-1

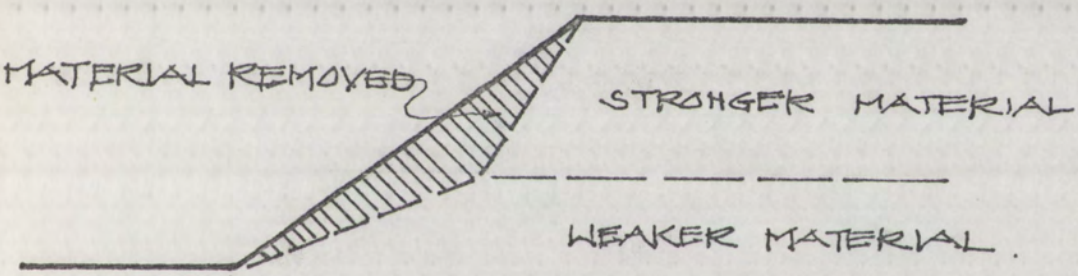


FIG. 3-2

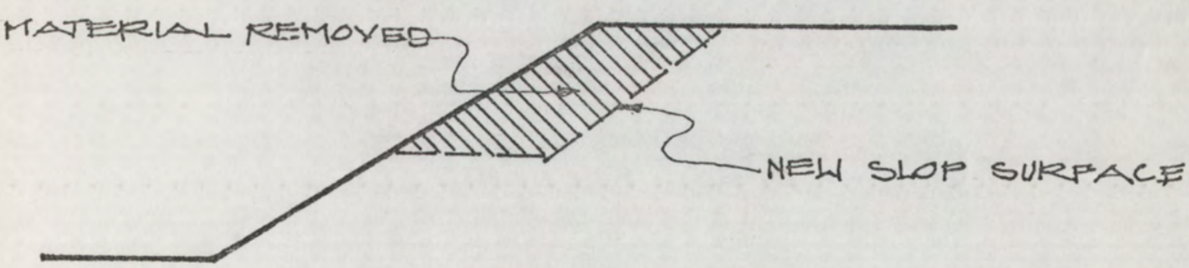


FIG. 3-3

Figure 3: Removal of weight on slope

further water from penetrating the slope.

a) Removal of water

Drain is extensively used as a remedy for slips. Usually the trench runs at right angles to the length of the slope, extending beyond the slip plane. The distance between drains depends upon the conditions and the use of auxiliary drains, but can be 10 feet to 30 feet.

The trenches are filled with clean hardcore brick rubble or similar suitable material. The side may be packed by hand before filling to produce a dry stone wall in the trench which will support the sides.

b) Interception of surface water before it reaches the slope.

This method not only reduces the water entering the material and the aggravation to the deep stability of the slope, but also reduces the erosion damage caused by water flowing down the slope surface.

Treatment of surface erosion

Surface erosion of slopes is usually caused by water moving rapidly over the surface, so that the greater the quantity of water falling, the greater the erosion risk.

It is generally less difficult to avoid damage to surface vegetation than to attempt its re-establishment after erosion has begun. The quantity of water falling, such as rain, on the slope itself may not be very large; but the catchment area from which rainwater collects to run down the slope may be considerable.

Methods

a) Drainage

Water from the catchment area is cut off and diverted before it reaches the slope. Interceptor drains laid along the top of the slope lead the water away, and must do so rapidly or the collected water may seep into the slope and aggravate deep instability.

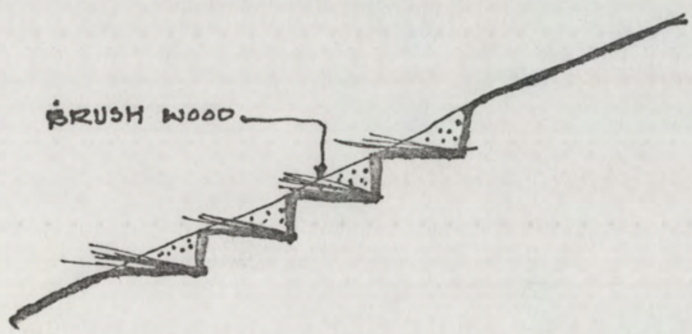
Sand of some cohesive strength may be excavated from a steep slope providing water is prevented from running down the slope surface. This can be done by laying a waterproof surface at the top of the slope 6 feet to 10 feet from the edge, with a fall away from the slope.

b) Pitching

The slope surface is protect by a complete covering of erosion resistant material such as brick, stone, concrete blocks, concrete, bitumen. This covering prevents the surface from being attacked by heavy rain, and takes surface runoff away from the soil surface.

c) Terracing

Terracing is used to reduce surface erosion by slowing down the flow of water on the slope. It relieves the gradient of slope allowing surface flowing water to percolate into the material providing platform of moist and level soil for the establishment of vegetation.



d) Vegetational

Vegetational methods of remedying surface instability are cheaper than constructional methods.

F. Analysis of form—effected by slope

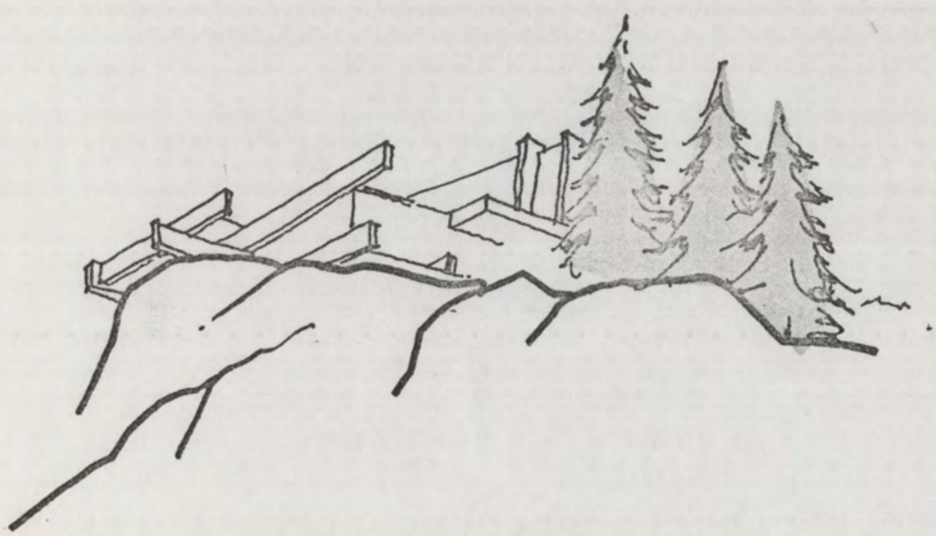
Basic form can be readily studied when it is specifically applied to a given subject, e.g. in the environmental design for a new village in terms of the planning form; or the massing of architectural elements, or the design of a specific object, and in any situation where the use of form by the designer is well defined from known or required functions.

Some general observations can be made concerning basic form and profile—where the profile and surface of a basic element are discernible, they should appear compatible, e.g. of similar size; both should appear irregular, jagged and hard; or smooth and soft, and be consistent with the known characteristics of the material from which the element is constructed.

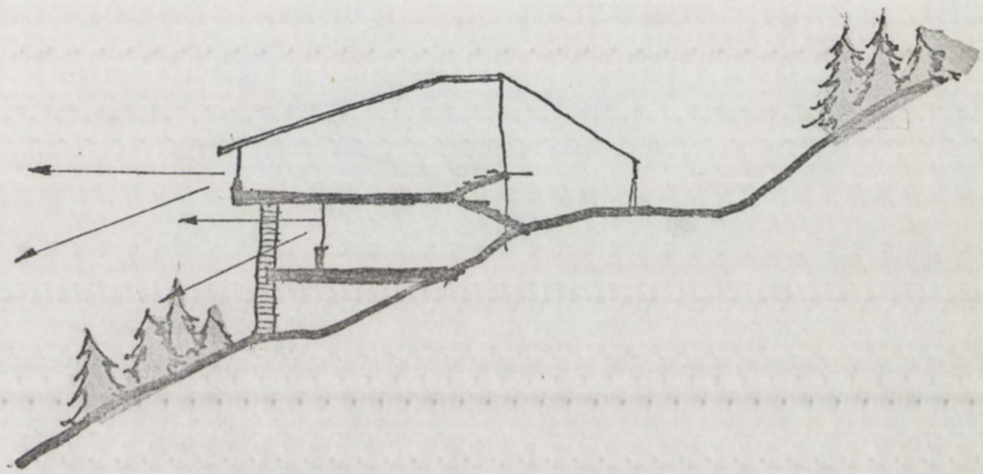
A basic form may be static, in apparent or actual motion, regular, irregular, symmetrical, asymmetrical, formal, informal, geometrical, predominantly solid, heavy and hard, predominantly translucent, transparent, light, smooth, patterned, textured and so on. Certain basic geometric forms quite common in architectural design exhibit elementary abstract qualities, and such forms are often derived from a rational use of structural materials and systems.

Because the sloping site has variable topography, there is a dynamic,irregular and feeling of motion; therefore, the form and function effected by the slope are as follow:

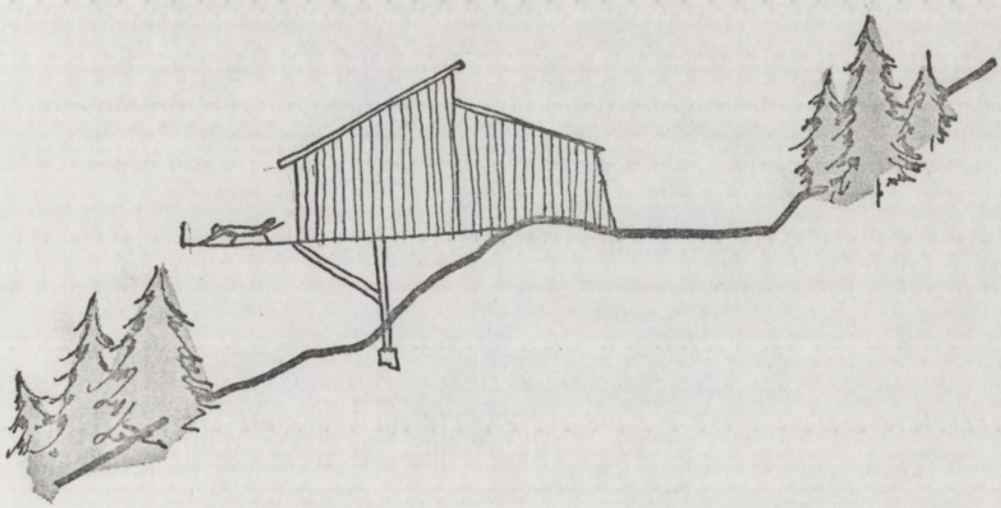
1. The forms must express the stability to cope with the gravity down the slope.
2. The grade change may be accentuated and dramatized through the use of flying terraces.



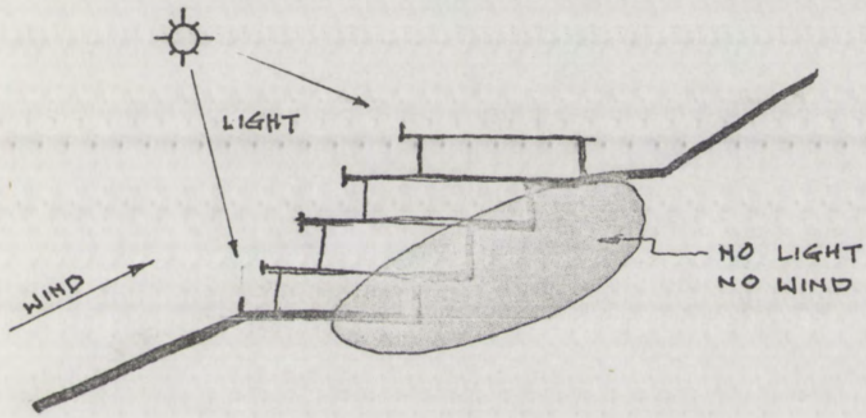
3. View is one of the most important factor on sloping site, windows must set outward.



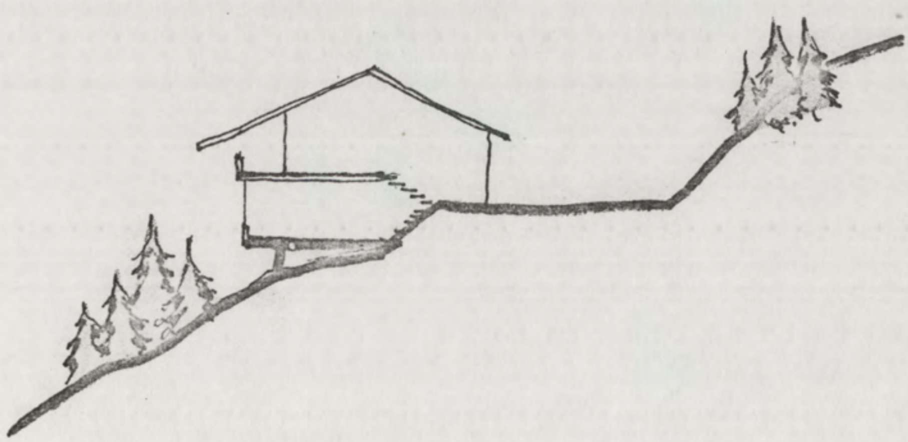
4. Balconies or decks are desired.



5. Flat sites are narrow or do not exist, so the plane form as bars or ribbons are suggest.
6. In contour rise type, one side of the structure is hugged by the slope and lacks sufficient natural light and air. Strip plane forms are desired to derive the better view, light and air.



7. Levels may separate functions as in split—level or multideck structures.



DESIGN CRITERIA

V. DESIGN CRITERIA

Sloping site has a very complex topography and the variety of all natural, culture and aesthetic factors affect the decisions when designing. The following section is devoted to the necessity of site investigation on sloping site and the basic concepts when designing.

A. Site analysis

Site investigations made concurrently with the formulation of program objectives ensure the flexibility of the site's potential and integration of its natural features with the design. In order to develop the best possible site for accommodating project objectives, a program must be carefully prepared.

The analysis of the site will be helpful in establishing guidelines for development. Any information that is inventoried should be illustrated graphically whenever possible, in order to communicate more completely. In these illustrations important factors may be abstracted, or isolated and emphasized, to build a firm foundation from which to interrelate all the known elements.

1. Topographic surveys

The analysis of a site and its environs presupposes that topographic maps have been obtained. Surveyors shall do all field work necessary to determine accurately the phyical condition existing on the site.

Information required on topographic maps

a) Title, location, owner's name, engineer, certification, and date.

b) True and magnetic north, scale.

c) Property lines, building lines.

d) Existing easements, rights-of-way on or adjacent to site.

e) Names of property owners on adjacent sites.

f) Location of structures on site.

g) Location and sizes of storm and sewage systems; manholes, catch basins, and curb inlet drains with rim and invert elevations.

h) Outline of wooded areas, location, elevation on ground, and type and size of trees with 3-4 inch trunk caliper or larger.

i) Hydrographic features--rivers, lakes, streams, swamps;

j) Location of telephone poles, light standards, fire hydrants.

k) Rock outcrops or other outstanding site features.

l) Road elevations at intervals of 50 ft.

m) Grid system of elevations at intervals of 50 ft.

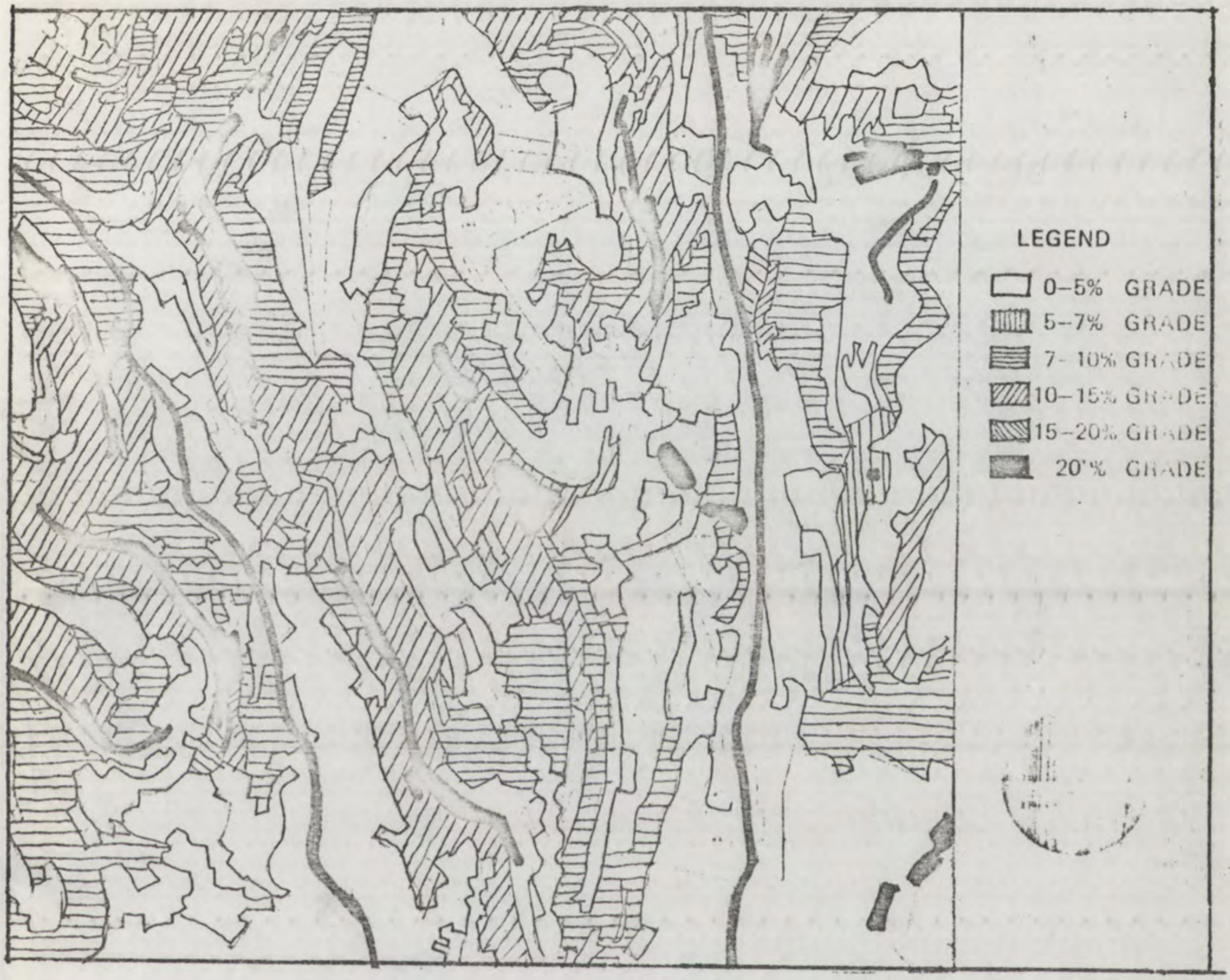
n) Contours at 1,2 or 5 ft. intervals.

Graphic survey information is essential, but it must be supplemented with at least one and preferably several visits to the site. Only by actual site observation can one get the "feel" of the property, sense its relationship to the surrounding areas, and become fully aware of the lay of the land.

2. Slope analysis

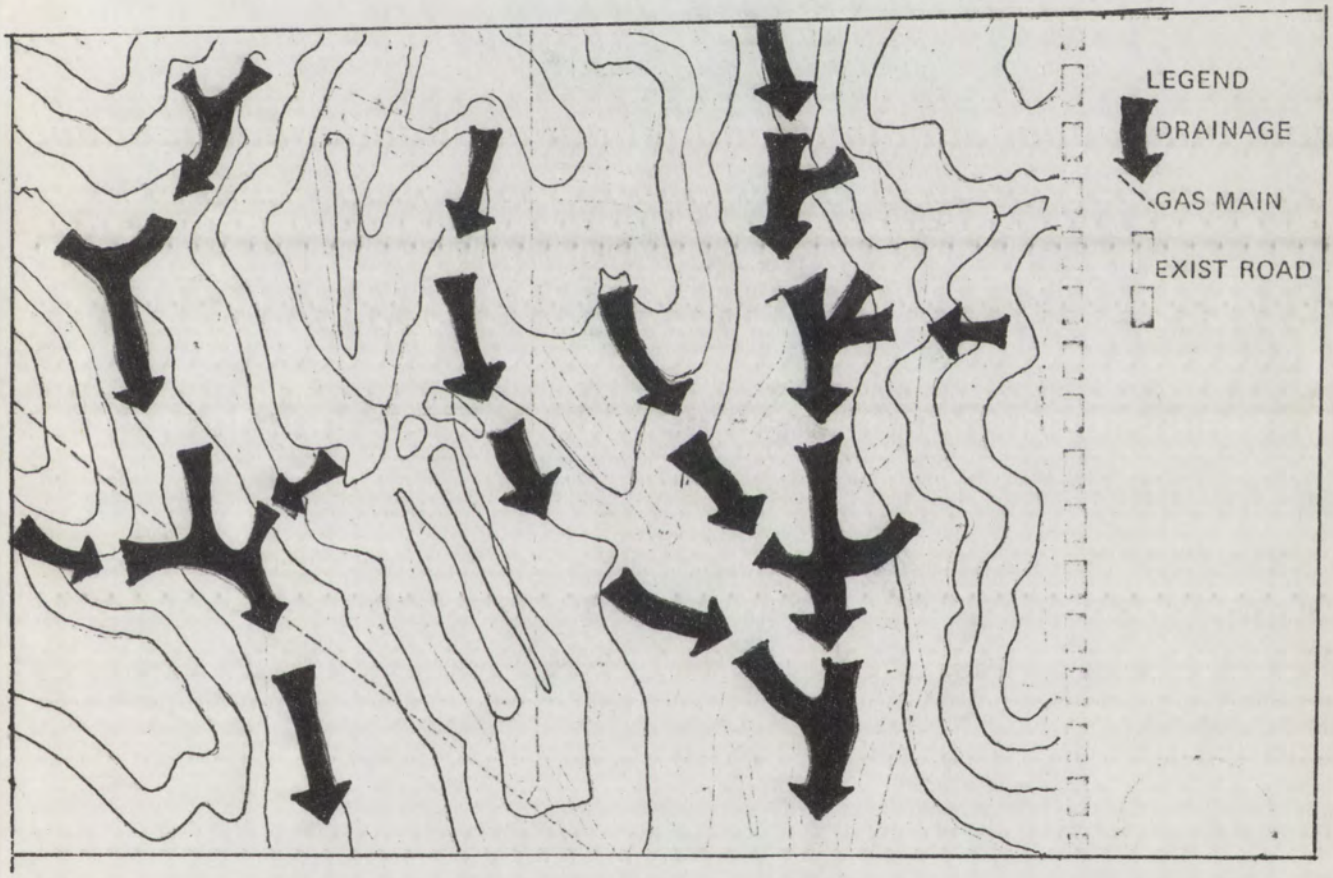
A slope analysis aids in recognizing areas on the site that lend themselves to building locations, roads, parking, and play areas. It may also show if construction is feasible. A parking lot, for example, should have a grade of under 5%. If there is no land available which meets this requirement, regrading will be necessary. The cost of grading may determine if the development of a site is feasible.

The over-all pattern of slopes will emerge through slope analysis, which helps the site planner determine the best land use for various portions of the site, along with feasibility of construction.



3. Hydrography

The drainage patterns on a site may greatly influence a design. All water bodies, rivers, streams, and drainage channels must be traced diagrammatically in order to be assayed and used advantageously. Hydrographic features which have a bearing on relating activities to the land are of primary importance in developing site drainage plan that makes use of existing watershed drainage patterns.



4. <u>Soils</u>

Consider the characteristics of the site, both surface and subsurface. At what depth is the water table located?

Percolation tests should be used to determine the rate of the infiltration or passage of water into the soil surface. Runoff occurs when precipitation exceeds infiltration rates. Drainage patterns on the site, therefore, may best be traced while it is raining.

The depth of water table is most important. If it is too close to the surface 6 ft.± there will be adverse effects on a building's basement and the project's cost will rise as increased waterproofing, pumping, and the use of pilings become necessary. If the water table is too low, costly problems concerning water supply may occur.

In areas where septic tanks are to be used in conjunction with residential development, the ability of soils to absorb and degrade sewage effluent quickly must be studied. If the soil is not suited for this use, problems such as water pollution and the smell of raw sewage will occur.

5. Vegetation

By observation of the vegetation on a site before development, one may make use of large existing trees rather than destroying them and later being forced to purchase small ones which will take many years to attain maturity. If a site is heavily wooded, a carefully planned method of thinning of the trees may open potential vistas.

Review the ecology of the surrounding area to find which trees or shrubs are native and which varieties may be added for wind protection, shade, buffer zones, screens, or backdrops. Having previously reviewed soil characteristics, the analysis should also investigate which, if any, nutrients must be added to the soil for improved plant growth.

6. <u>Climatic factors</u>

Elevation differences, character of the topography, vegetation and ground cover, and water bodies influence the climate, which in turn affects the site.

For each 300 ft. rise in height from the earth's surface, temperature decreases approximately 1° F in the summer. Different topographic heights affect the microclimate; cool air flows toward low points or valleys at night while the higher side of the slopes remain warm.

Climates can be divided into four general types--cool, temperate, hot arid, and hot humid.[1] In each of these climatic zones the site planner should investigate the solar orientation for buildings, the best facing slopes, and the part of the slope that makes use of air flow for warmth in cool climates and for breezes in the temperate or hot climates.

B. <u>Design concept</u>

Steep slopes or drops are usually difficult to handle within a regularly organized space: it is a safe rule to take

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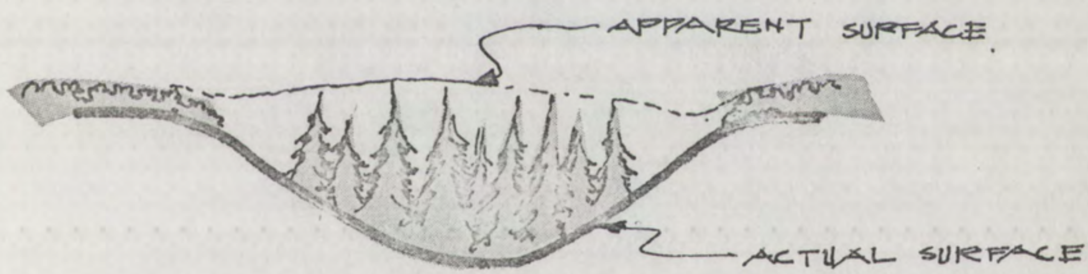
1 Victor Olgyay, <u>Design with Climate</u>, Princeton, New Jersey, Princeton University Press, 1973. P. 52.

up such vertical differences in the approach to, or between, important openings. Level changes may be used to define space by themselves, and they add many additional visual possibilities, whether of view, silhouette, truncation, or dynamic contour line. The building or road can be set low to the ground, and the natural contours are left as undisturbed as possible. This often proves to be the least expensive solution as well. At other times, the best solution (in terms of cost and as esthetics) may be just the opposite: to allow the road or the axis of the building to plunge directly across the contours. This is a dramatic method which often clarifies the topography in the strongest possible way. The most difficult relationships occurs when the structural axes are diagonal to the contours. This solution is occasionally successful in skillful hands, but most often is liable to be awkward.

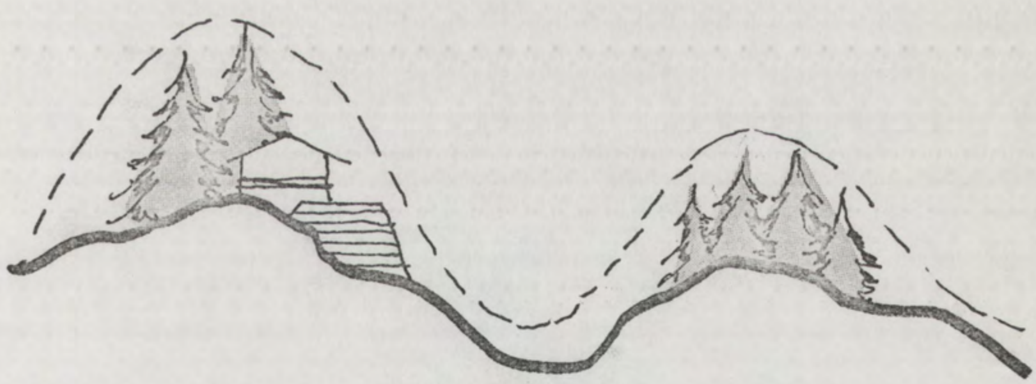
The designer must go beyond such local relationships if he wishes to clarify the basic structure of the land. He will arrange views and approaches so that the full scale of the hills and valleys may be appreciated and their character most sharply brought out. Sometimes this is best accomplished by "unnatural" designs, such as those which plant the hills and clear the valley bottoms to emphasize the drainage compartments, or those which make a deep cut through a crest, so as to expose the earth or to make more dramatic the entrance into a valley. A town such as San Francisco, whose streets definitely ignore the contours, is in fact very expressive of its dramatic site. The "natural" landscape pattern, with tall trees on the rich bottom land, and dwarf plants on the hills, actually tends to blur the sense of the underlying ground.



Buildings of uniform height, with their differentiated planes of roof and facade, may be arranged in a step fashion on a hill, to give the sense of "piling up". Tall buildings may be placed on the heights, and low structures in the valleys.

Long slabs may set back in echelon as they climb, or they may be stepped in vertical section. Special views may be opened up from the lowest to the highest points, and vice versa.

Inevitably, a new development changes the existing contours in a substantial way. These new ground shapes should fit harmoniously into the older landscape, or else be obvious, artificial intrusions. If a harmonious fit is desired, transitions must be smoothly made, new land forms must be of the same family as the existing land forms, both in shape and scale.



SUMMARY

VI. SUMMARY

The main objective of this thesis was to study the reasons, advantages and problems involved in hillside housing.

The topic is especially critical in a crowded country such as Taiwan, where the only available land for building is sloped. To investigate this topic, the advantages and disadvantages of hillside housing were pointed out by through a comparision with flat level housing. The problems involved in the sloping site such as climate, utilities, access, slope stability, structural methods and forms effected by slope must be identified and finally establish the design criteria.

On sloping sites there is no single technology; there are many, and none are universally applicable to all building situation. The difficulty in practice is how to interrelate and give balance and weight to the design principle.

The following charts provide an overview of the design procedure, problems related to design consideration and design recommendations.

Chart 1 is a diagram of the design procedure; Chart 2 shows the relationship between design considerations and site components on sloping site. Black dots in the center of each intersection shows the amount of correspondence between elements at either side. The larger the dot the greater the correlation, no dot indicates no correlation; Chart 3 lists site components with graphic and comments for design recommendation.

Chart 1: DIAGRAMMATIC OF DESIGN PROCEDURE

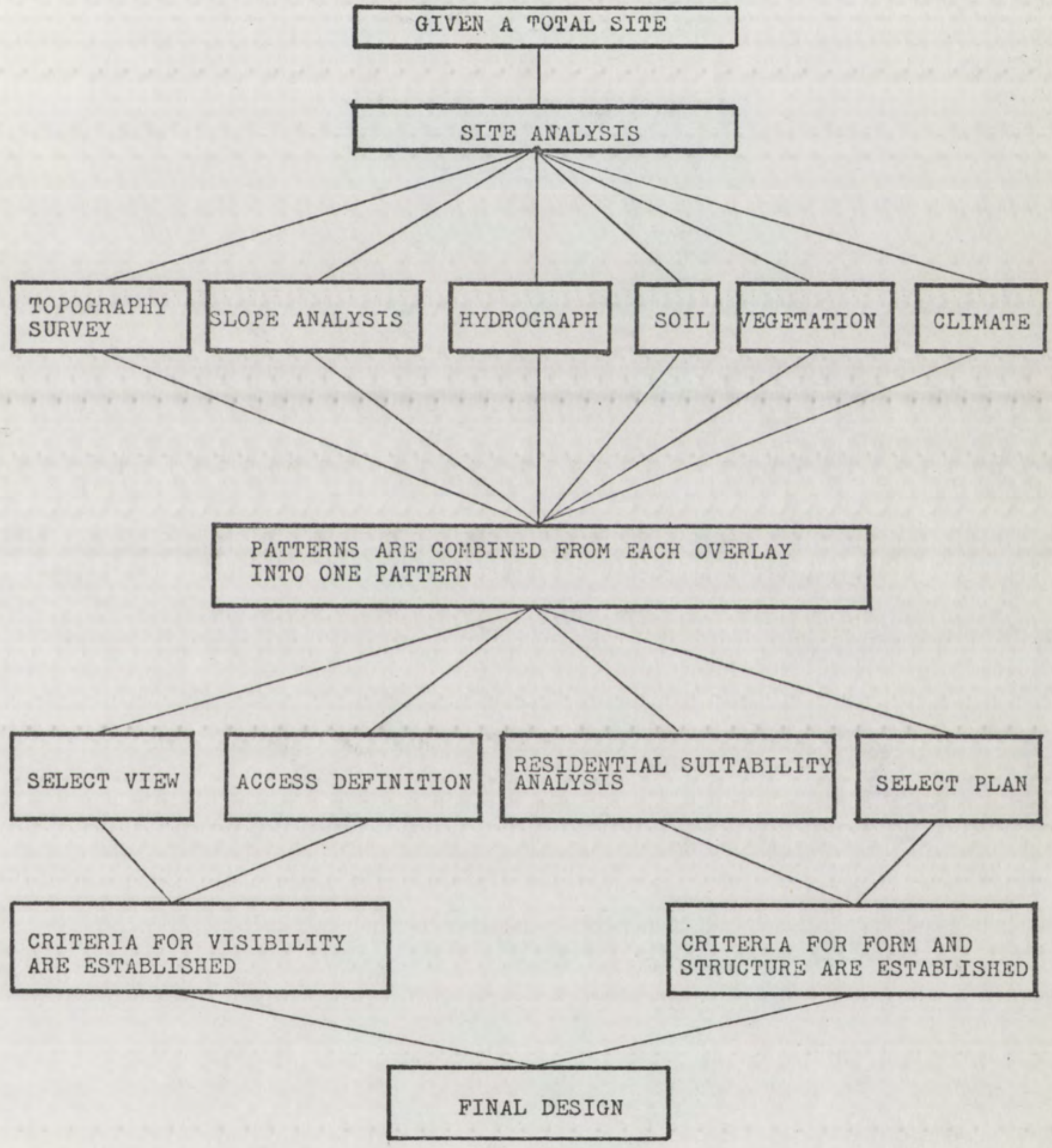
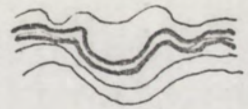
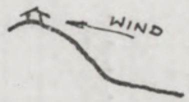
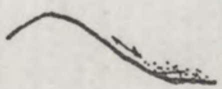


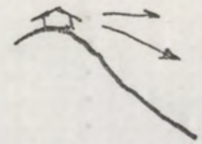
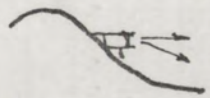
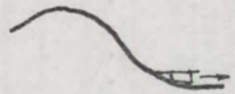
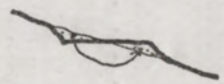
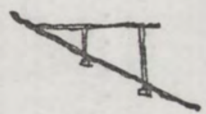
Chart 2: RELATIONSHIP BETWEEN SITE COMPONENTS AND DESIGN CONSIDERATIONS

	Site Components	Design Considerations											
		Access	Earth Work	Foundation	Form	Function	Structure Method	Gradient	Utilities	Orientation	Slide Control	Erosion Control	Landscaping
Aesthetics	View & Vista	●				●				●			
	Open Space Quality					●				●			
	Landscape	●	●					●		●			●
Vegetation	Trees									●	●	●	●
	Shrubs									●	●	●	●
	Grass									●	●	●	●
Geology	Land Form	●	●	●	●	●	●						●
	Soil		●	●			●	●					
	Construction Material		●	●			●	●			●		
Water	Surface	●						●			●	●	
	Underground										●		
	Snow, Ice	●			●								
Processes	Drainage							●	●				
	Flood												
	Erosion							●					
	Stability (slides, slump)							●					
Climate	Air Movement				●			●					
	Diffuse Radiation				●								

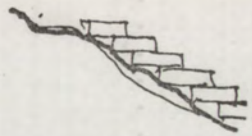
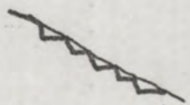
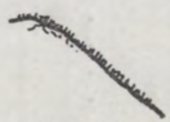
Chart 3 DESIGN RECOMMENDATIONS

Components	Description	Graphic	Comments	Page
Access	Along the contour		1. Sewer difficulties 2. Separate utilities are suggested 3. Easiest and cheapest to develop	42
	Perpendicular to the contour		1. Utilities may become too steep 2. Rear lots may have awkward cross 3. Step-down building types are suggested	44
	Diagonal to the contours		1. Most difficult to use. 2. Use only where slopes are gentle or too steep, where neither paralle nor perpendicular road will serve	43
Climate	Top slope		1. Excessive wind	29
	Middle slope		1. Preferable to prevent excessive wind and to avoid cool air pool	31
	Bottom slope		1. Cool air pool	30

Continued

View	Top slope		1. Good view and vista 2. Structure exposed to the elements	22
	Middle slope		1. Desirable view 2. Structure not too exposed to the elements	22
	Bottom slope		1. View is poor	22
Structure methods	Terracing and retaining wall		1. Using in gentle slopes 2. Need earth cut and fill	38
	Vertically supported		1. Used on steep slopes 2. Best to preserve the natural park land 3. Used on single units mostly 4. Needs no cut and fill	40
	Terracing and vertically supported combination		1. Used in a sloping site with different 2. Needs cut and fill	40

Continued

	Vertical wall support		1. Used on high density design 2. Needs no earth cut and fill	41
	Cantilever		1. Used in difficult foundation 2. Used when slope is very deep 3. No cut and fill needed	42
Erosion control	Drainage		1. Prevent water flowing down the slope surface	58
	Pitching		1. Protect the slope surface by covering	59
	Terracing		1. Reduce the runoff speed 2. Provide a platform of moist and level soil for the establishment of vegetation	59
	Vegetation		1. Cheapest and easiest way for erosion control 2. Provide better landscape	60

Continued

Slide slump	External support		1. Permanent remedies 2. Expensive 3. Must provide drainage of water through the structure	54
	Removal of weight		1. Reducing the angle of the slope 2. Constructing different angles of slopes 3. Terracing	55
	Strengthening the slope		1. Using trench to remove the water 2. Intercept the water before it reaches the slope	57

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